APPENDIX G
GRAND CANAL CONCEPTUAL PLAN-HYDROLOGY PLAN

GRAND CANAL CONCEPTUAL PLAN - HYDROLOGY MODELING

Prepared for

Psomas Ltd

Prepared by

Philip Williams & Associates, Ltd.

October 2007

PWA REF. # 1898

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1. INTRODUCTION

This appendix describes the numerical modeling to evaluate the hydrologic alternatives for the Grand Canal Conceptual Plan. The Environmental Fluid Dynamics Code (EFDC) model (Hamrick 1992, Tetra Tech 2002) was configured to evaluate different system configurations and hydrologic scenarios. The results of the modeling were used to determine how well the alternatives met the project objectives and how well they compared with existing conditions.

The hydrologic objectives of the project are:

- To maximize tidal range within Grand Canal;
- To reduce residence time within Grand Canal;
- To maintain the existing level of flood protection along Grand Canal and Ballona Lagoon.

The system configuration termed 'Existing Conditions' in this study is not the actual configuration present today. The City of Los Angeles stipulated that the proposed Marina del Rey Tide Gates Rehabilitation (LADPW 2007) be treated as existing conditions since this project is being implemented.

2. CONCLUSIONS

- Under Existing Conditions, the average tide range in Grand Canal varies between -1.3 ft MSL and 1.9 ft MSL from mid-April to mid-October and between -1.3 ft MSL and 0.3 ft MSL from mid-October to mid-April. The minimum water level is determined by the bed elevation as Grand Canal dries out at the lowest tides. The maximum water level is determined by the Marina del Rey tide gates' operational setting.

- The proposed Operational Alternative, which dictates reduced water levels only when rainfall is predicted, decreases the total duration of the reduced tidal range within Grand Canal from 50% annually to less than 20%. It also reduces the total duration of periods when high tide water levels vary from one tide to the next.

- Planned rehabilitation of the Marina del Rey tide gates has sufficient conveyance capacity that water levels in the Grand Canal closely follow oceanic tides, except when limited by bed elevation or tide gate closures. Therefore, improvements in tidal range resulting from any Structural Alternative would be minimal.

- To flush the Venice Canals, the Washington St. culverts are opened for 2-6 hours approximately twice a week. When these culverts are open, high tide and low tide in the Grand Canal are each damped by 0.3 to 0.6 ft.

- During the 50-year flood event, predicted water levels in the Grand Canal peak at 2.2 ft MSL and drain completely on the subsequent low tide.

- During Existing Conditions Dry Mode gate operations, average residence time in Ballona Lagoon and Grand Canal is just longer than one tidal cycle. Mean residence time increases by a factor of three during Wet Mode gate operations.

- By reducing the duration of restricted tidal range and residence time, the Operational Alternative would reduce the duration of freshwater inundation following flood events.

3. MODELING SETUP

3.1 HYDROLOGIC SCENARIOS

The Grand Canal is exposed to oceanic tides via tide gates at the mouth of Ballona Lagoon that connects to Marina del Rey and Santa Monica Bay. As such, the configuration of the Marina del Rey tide gates is the primary determinant of the water levels in the Grand Canal. Observations have indicated that water levels within the Grand Canal and Ballona Lagoon, the waterway seaward of the Canal, change nearly uniformly throughout the Canal and Lagoon with minimal spatial variation. Observed water levels from NOAA (Station ID 9410660) for the two-week spring-neap period from July 7 to July 21, 2006 were used as the open boundary condition forcing the model in Santa Monica Bay.

Two hydrologic scenarios were considered for each alternative:

1. no stormwater discharge; and
2. the extreme flood corresponding to the 50-year, 96-hour event.

These two scenarios bound the range of conditions for which the system is designed. The discharge for the flood scenario was estimated according to the County of Los Angeles Hydrology Manual (LADPW 2006) and stormwater sewer data provided by the City of Los Angles staff.

3.2 SYSTEM CONFIGURATION

3.2.1 Existing Conditions

The system configuration termed ‘Existing Conditions’ is not the actual configuration on the ground today. Rather, the City of Los Angeles stipulated that the proposed Marina del Rey Tide Gates Rehabilitation be treated as existing conditions for this study since this project is already being implemented. The physical specifications and operational plan for this rehabilitation plan were determined from the design drawings (LADPW 2007) and incorporated into the model. The operational plan calls for changing the cutoff water level for the automatic closure of the Marina del Rey tide gates twice a year to provide greater tide range during the summer and smaller tide range and increased flood protection during the winter. The maximum design water level is 2.7 feet Mean Sea Level (MSL). The specifications for the two modes are:

- **Dry Mode** – From mid-April to mid-October, the gates are closed when the Marina water level exceeds 2.25 feet MSL and the Marina water level is more than 0.25 feet higher than the Ballona Lagoon water level.

- **Wet Mode** –From mid-October to mid-April, the gates are closed when the Marina water level exceeds 0.0 feet MSL and the Marina water level is more than 0.25 feet higher than the Ballona Lagoon water level.

In both modes, the gates re-open when Marina water levels drop below Lagoon water levels.

3.2.2 Operational Alternative

The proposed Operational Alternative altered the Marina del Rey tide gate operations so that the Wet Mode is only implemented in response to storm forecasts. An analysis of 13 years of daily rainfall in Santa Monica[1] provided a hindcast estimate of the annual frequency at which the gates would be operated in Wet Mode. These estimates can be compared to Existing Conditions, which would be in Wet Mode for 50% of the time (six months out of the year). If the Wet Mode was implemented for two days on either side of any rainfall 0.25 inches or greater, the gates would have been set to Wet Mode for an average of 13% of the 13-year precipitation record. For the driest (2002) and wettest (2005) water years of this record, Wet Mode would have been in effect 7% and 20% of the time, respectively.

3.2.3 Structural Alternative

Initial modeling demonstrates that the Existing Conditions of the Marina del Rey tide gates provided sufficient conveyance capacity to enable water levels landward of the culvert to nearly match the oceanic tidal range, excepting water levels above the cutoff elevation. A structural alternative to further expand the capacity of the gates would likely incur significant costs for minimal gain in tidal range. Therefore, no further modeling of the structural alternative was undertaken and structural changes to the Marina del Rey tide gates are not recommended.

3.3 WASHINGTON ST. CULVERTS AND VENICE CANALS

For all results presented in section 5, the Washington Street culverts, which connect Grand Canal to the Venice Canals, were closed. Personal communication with Mariposa Landscaping, the company that operates the culverts, indicates that that they are only open between 2 to 6 hours for 1 to 3 times a week. To test the effect of having these gates open, a sensitivity analysis was conducted to compare water levels between cases when the culverts were either open or closed throughout the entire simulation period. When the culverts were open, high tide water levels

[1] CIMIS Station #99 (Santa Monica) daily precipitation data for water year 1994 to water year 2006.

decrease and low tide water levels increase by a similar magnitude of 0.3 to 0.6 feet. Even if the culverts were opened for a maximum of three 6-hour periods per week (10% of the time), the impacts on the integrated water level statistics (MHHW, MLLW, annual inundation frequency, etc.) should be small.

4. MODELING RESULTS

4.1 TIME SERIES OF WATER LEVELS – NO STORMWATER DISCHARGE

4.1.1 Dry Mode

Time series of water levels under the Dry Mode configuration of the Marina del Rey tide gates are shown in
. Both Ballona Lagoon and Grand Canal exhibited muted tidal range as compared to the oceanic tides in Marina del Rey. The deeper sections of Ballona Lagoon experience nearly the same low tide as the Marina.

For most of the spring-neap cycle, high tide water levels within the Canal were below 2.0 feet MSL. During two neap high tides (day 14), water levels peaked at 2.1 feet MSL because peak Marina water levels occured close to the gates' controlling water level of 2.25 feet MSL. Overall, the spring-neap variability in tide range, nearly a factor of two in the Marina tides, was significantly diminished within the Canal.

4.1.2 Wet Mode

Time series of water levels under the Wet Mode configuration of the tide gates are depicted in
Figure 2. During Dry Mode, the peak water levels within Grand Canal were reduced to approximately 0.5 feet MSL and minimum water levels occur when the channel bed dried out at -1.3 feet MSL. Because peak allowable water levels are reached more quickly, water levels in Grand Canal remained constant for a longer period of time as compared with Dry Mode operations. In Wet Mode, the discharge through the tide gates was more sensitive to the rate of change of Marina water levels. This produced more variability in water levels over the spring-neap cycle than during Dry Mode operations.

4.2 TIME SERIES OF WATER LEVELS – EXTREME FLOOD CONDITIONS

While greater tidal range in Grand Canal is a primary objective of the project, this range cannot be expanded at the cost of greater flood risk. To evaluate potential changes to the flood risk as a result of the alternatives, the 50-year stormwater discharge event during Wet Mode operations was evaluated with the model. Figure 3 presents the time series of water levels under these extreme flood conditions. Even during the maximum flood discharge at 10.8 days, water levels in the project area peaked at 1.8 feet MSL, 0.9 feet less than the maximum design water level of 2.7 feet MSL

The extreme flood conditions depicted in Figure 3 did not include flows from the Venice Canals through the Washington St. culverts. The culverts are unlikely to be opened during peak water levels of a flood event since this would expose the property adjacent to the Venice Canals to potential flooding from the Grand Canal. Instead, the culverts would only be opened for periods during which the Grand Canal water levels are less than the Venice Canals' water levels (P. comm., Mariposa Landscaping). As a conservative scenario, a model simulation was conducted with the Washington St. culverts open throughout the extreme flood. For this case, model predictions indicated that peak water levels in Grand Canal would be approximately 0.3 feet higher than when the culverts are closed. This maximum water level of 2.1 feet MSL was still below the maximum design water level of 2.7 feet MSL.

The Operational Alternative relies on the switching between Dry Mode and Wet Mode when storms are forecasted. To test how the system would respond if this switch did not occur, the 50-year stormwater discharge event during Dry Mode operations was evaluated with the model. 4 presents the time series of water levels under these extreme flood conditions. During the maximum flood discharge at 10.8 days, water levels in the project area peaked at 2.6 feet MSL, 0.1 feet less than the maximum design water level of 2.7 feet MSL.

4.3 TIDAL DATUMS

The tidal datums of Mean Higher High Water (MHHW), Mean Sea Level (MSL), and Mean Lower Low Water (MLLW) characterize a time-varying water level record into a few key values. Table 1 summarizes these values for Marina del Rey and the Grand Canal under different system configurations and hydrologic scenarios. The largest difference between Dry Mode and Wet Mode occurs for high tide (maximum water level and MHHW) whereas low tide (MLLW) is relatively unchanged. The maximum water level predicted for the extreme flood event during Wet Mode operations falls below the maximum water level during Dry Mode operations.

Table 1 Tidal datums and tide range from two weeks of EFDC model predictions (tidal datums in ft MSL)

Tidal Datum, feet MSL	Marina del Rey	Grand Canal		
		Dry Mode	Wet Mode	Wet Mode, Extreme flood
Maximum water level	4.2	2.1	0.7	1.8
MHHW	3.4	1.9	0.3	0.6
MSL	0.3	0.3	-0.4	-0.4
MLLW	-3.1	-1.3	-1.2	-1.3
Minimum water level	-4.2	-1.3	-1.3	-1.3

Tide range, feet (MHHW-MLLW)	6.5	3.2	1.5	1.9

4.4 ANNUAL INUNDATION FREQUENCY

An integrated summary of water levels which can be correlated with habitat is inundation frequency, presented as the relationship between water level and the percentage of time that this water level is exceeded. To extend from the two weeks of simulation time to annual frequency, the weighted average of the Dry Mode and Wet Mode inundation frequencies was calculated. For Existing Conditions, both Dry and Wet Mode were weighted equally to represent their equal implementation for six months of the year. For the Operational Alternative, the weights are based on the rainfall frequency analysis discussed above. The Wet Mode inundation frequency is weighted as 13% of the year and Dry Mode inundation frequency as the remaining 87%.

The resulting inundation frequency relationships are shown in Figure 5. Compared to an entire year of water level observations in Santa Monica Bay, the inundation frequencies within Grand Canal are compressed into a smaller tidal range. The Operational Alternative demonstrates a consistent increase of 0.5 feet in water level exceeded from 0% to 70% of the time as compared to the Existing Conditions.

4.5 TIDAL PRISM AND RESIDENCE TIME

The tidal prism was calculated by summing the discharge through the Marina del Rey tide gates to determine the volume of water exchanged between the Marina and Ballona Lagoon and Grand Canal on each tide. The residence time, calculated as the total volume in the Lagoon and Canal divided by the tidal prism, provides an estimate of how long it takes for all the water in the Lagoon and Canal to be replaced with water from the ocean.

Results of these calculations, presented in Table 2, indicate that tidal prism decreases by a factor of three between Wet Mode and Dry Mode. Residence time correspondingly increases by a factor of three. By reducing the amount of time which Wet Mode operations are in effect, the Operational Alternative would reduce the amount of time that the tidal prism is reduced and residence time increases. Additionally, by returning to Dry Mode soon after a flood event, the Operational Alternative would more quickly purge fresh and potentially polluted stormwater runoff from the Lagoon and Canal, replacing it with clean, salty ocean water.

Table 2 Average tidal prism and residence time over a spring-neap cycle for Ballona Lagoon and Grand Canal.

	Dry Mode	Wet Mode
Tidal prism (acre-ft per tide)	25	9.7
Residence time (# tidal cycles)	1.1	3.2

5. LIST OF FIGURES

6. REFERENCES

Hamrick, J.M., 1992. 'A Three-Dimensional Environmental Fluid Dynamics Computer Code: Theoretical and Computational Aspects'. The College of William and Mary, Virginia Institute of Marine Science. Special Report 317, 63 pp.

LADPW, 2006. 'Hydrology Manual'. Water Resources Division, County of Los Angeles Department of Public Works.

LADPW, 2007, 'Marina del Rey Tide Gates Rehabilitation for Department of Beaches and Harbors'. County of Los Angeles Department of Public Works. Job #953, Sheets 1 to 15.

Tetra Tech, 2002. 'User's Manual for Environmental Fluid Dynamics Code: Hydro Version (EFDC-Hydro)'. Prepared for U.S. Environmental Protection Agency.

7. LIST OF PREPARERS

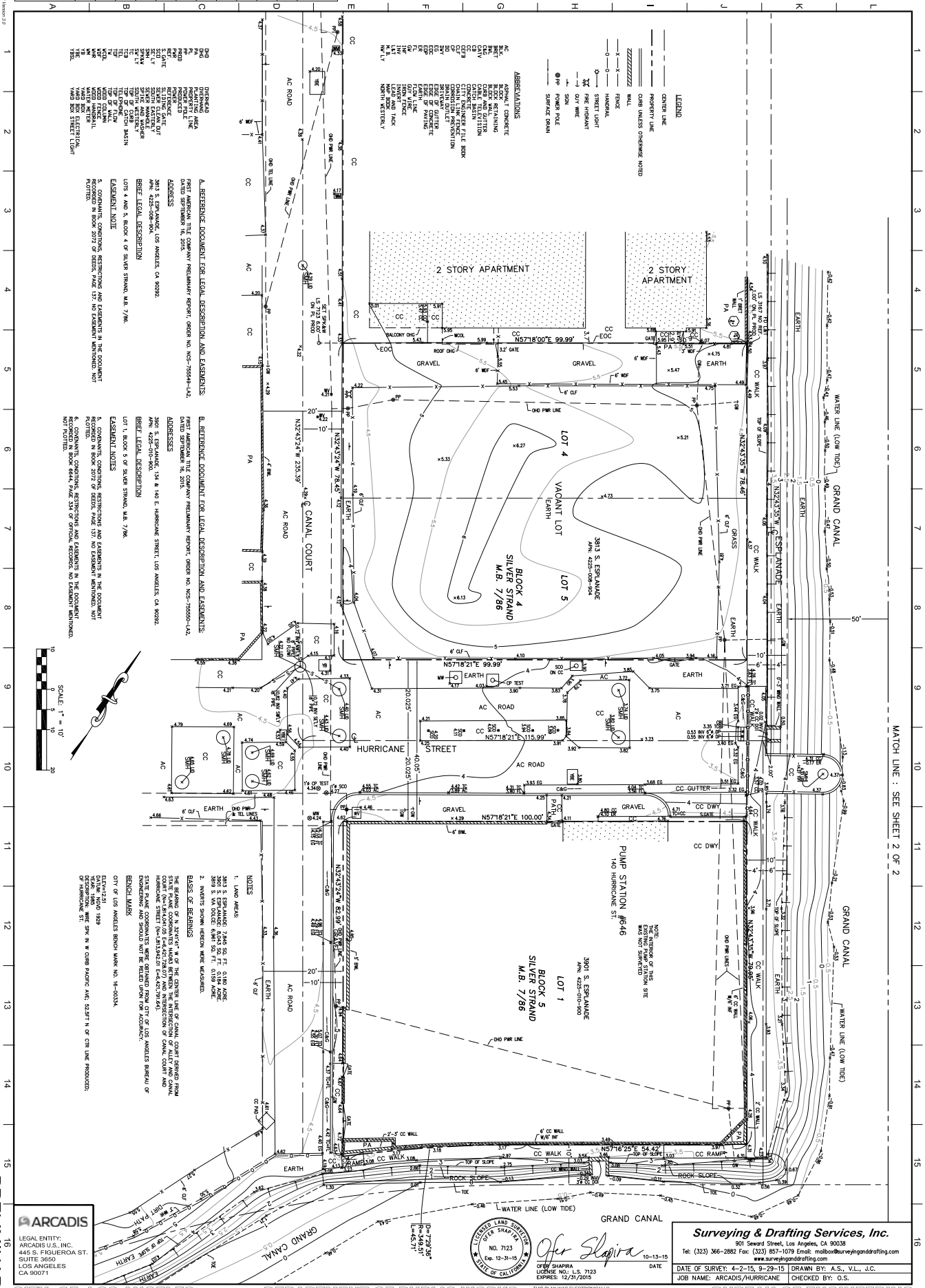
This report was prepared by the following PWA staff:

Jeff Haltiner – Project Director

Jeremy Lowe – Project Manager

Matt Brenann - Modeler

APPENDIX H
SURVEY OF VENICE AUXILIARY PUMPING PLANT SITE



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OHD OVERHEAD
CHD CHAIN DRIVE
PA PLANTING AREA
PPP POWER POLE
PWP POWER POLE
PP POWER POLE
PPRP POWER POLE
S. GATE SLIDING GATE
SCO SEWER CLEAN OUT
SMH SEWER MANHOLE
SSMH SEWER MANHOLE
SW LV SOUTH WESTERLY
TOB TOP OF BANK
TOC TOP OF CURB
TOE TOP OF EDGE
TOW TOP OF WALL
WDF WOOD FENCE
WM WATER METER
WV WATER VALVE
YBE YARD BOX ELECTRICAL
YBSL YARD BOX STREET LIGHT

A. REFERENCE DOCUMENT FOR LEGAL DESCRIPTION AND EASEMENTS:
FIRST AMERICAN TITLE COMPANY PRELIMINARY REPORT, ORDER NO. NCS-735549-LA2, DATED SEPTEMBER 1st, 2015.

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APN: 4225-008-904.

BRIEF LEGAL DESCRIPTION
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EASEMENT NOTE
5. COVENANTS, CONDITIONS, RESTRICTIONS AND EASEMENTS IN THE DOCUMENT RECORDED IN BOOK 2072 OF DEEDS, PAGE 137. NO EASEMENT MENTIONED. NOT PLOTTED.

B. REFERENCE DOCUMENT FOR LEGAL DESCRIPTION AND EASEMENTS:
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3813 S. ESPLANADE: 7,845 SQ. FT. 0.180 ACRE
3901 S. ESPLANADE: 6,981 SQ. FT. 0.160 ACRE
3919 S. VIA LOUCE: 6,981 SQ. FT. 0.159 ACRE.
2. INVERTS SHOWN HEREON WERE MEASURED.

BASIS OF BEARINGS
THE BEARING OF N 32°41'41" W OF THE CENTER LINE OF CANAL COURT DERIVED FROM STATE PLANE COORDINATES BETWEEN THE INTERSECTION OF GRAND CANAL AND CANAL COURT (N=1,814,041.05 E=4,421,728.07) AND INTERSECTION OF CANAL COURT AND HURRICANE STREET (N=1,813,942.01 E=4,421,791.64).
STATE PLANE COORDINATES WERE OBTAINED FROM CITY OF LOS ANGELES BUREAU OF ENGINEERING AND SHOULD NOT BE RELIED UPON FOR ACCURACY.

BENCH MARK
CITY OF LOS ANGELES BENCH MARK NO. 16-00334.
ELEV=12.51
DATUM: NGVD 1929
LOCATION: WEST SIDE OF PACIFIC AVENUE, 52.5FT N OF CTR LINE PRODUCED, OF HURRICANE ST.
DESCRIPTION: WIRE SPK IN W CURB

NOTE: THE OWNER OF THIS EXISTING PUMP STATION, SITE WAS NOT SURVEYED

PRELIMINARY DESIGN

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LEGAL ENTITY:
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OFER SHAPIRA DATE
LICENSE NO.: L.S. 7123
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JOB NAME: ARCADIS/HURRICANE | CHECKED BY: O.S.

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VERTICAL CONTROL: NGVD 1929 (1985)
HORIZONTAL CONTROL: NAD83

GARY LEE MOORE, P.E. CITY ENGINEER

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SHEET TITLE: TOPOGRAPHIC SURVEY
PROJECT: VENICE AUXILIARY PUMPING PLANT
ADDRESS: 140 HURRICANE ST MARINA DEL REY, CALIFORNIA

INDEX NO. D-31898
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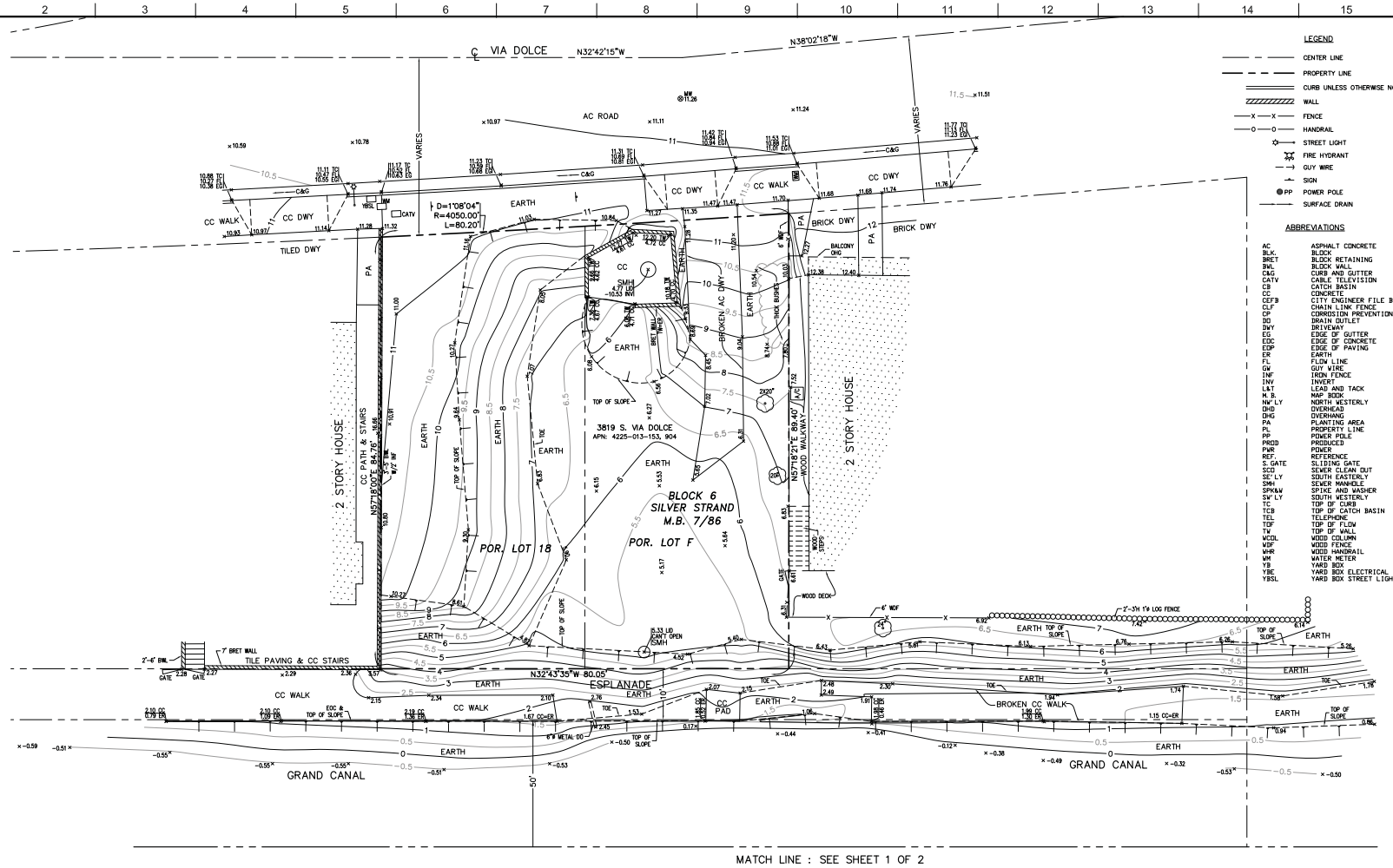

LEGEND

- CENTER LINE
- PROPERTY LINE
- CURB UNLESS OTHERWISE NOTED
- WALL
- FENCE
- HANDRAIL
- STREET LIGHT
- FIRE HYDRANT
- GUY WIRE
- SIGN
- POWER POLE
- SURFACE DRAIN

ABBREVIATIONS

AC	ASPHALT CONCRETE
BLK.	BLOCK
BRET	BLOCK RETAINING
BWL	BLOCK WALL
C&G	CURB AND GUTTER
CATV	CABLE TELEVISION
CB	CATCH BASIN
CC	CONCRETE
CCFB	CITY ENGINEER FILE BOOK
CLF	CHAIN LINK FENCE
CP	CORROSION PREVENTION
DO	DRAIN OUTLET
DWY	DRIVEWAY
EG	EDGE OF GUTTER
EGC	EDGE OF CONCRETE
EOP	EDGE OF PAVING
ER	EARTH
FL	FLOW LINE
GW	GUY WIRE
INF	IRON FENCE
INV	INVERT
L&T	LEAD AND TACK
M.B.	MAP BOOK
NW'LY	NORTH WESTERLY
OHD	OVERHEAD
OHG	OVERHANG
PA	PLANTING AREA
PL	PROPERTY LINE
PP	POWER POLE
PROD	PRODUCED
PWR	POWER
REF.	REFERENCE
S. GATE	SLIDING GATE
SCO	SEWER CLEAN OUT
SE'LY	SOUTH EASTERLY
SMH	SEWER MANHOLE
SPK&W	SPIKE AND WASHER
SW'LY	SOUTH WESTERLY
TC	TOP OF CURB
TCB	TOP OF CATCH BASIN
TEL	TELEPHONE
TOF	TOP OF FLOW
TW	TOP OF WALL
WCOL	WOOD COLUMN
WDF	WOOD FENCE
WHR	WOOD HANDRAIL
WM	WATER METER
YB	YARD BOX
YBE	YARD BOX ELECTRICAL
YBSL	YARD BOX STREET LIGHT

SCALE: 1" = 10'

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LEGAL ENTITY*:
ARCADIS U.S., INC.
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LOS ANGELES
CA 90071

CITY OF LOS ANGELES DEPARTMENT OF PUBLIC WORKS BUREAU OF ENGINEERING

VERTICAL CONTROL: NGVD 1929 (1960)
HORIZONTAL CONTROL: NAD83

SHEET TITLE: TOPOGRAPHIC SURVEY

PROJECT: VENICE AUXILIARY PUMPING PLANT

ADDRESS: 140 HURRICANE ST.
MARINA DEL REY, CALIFORNIA

GARY LEE MOORE, P.E. CITY ENGINEER

ENGINEER: DESIGN GROUP LIC. NO.
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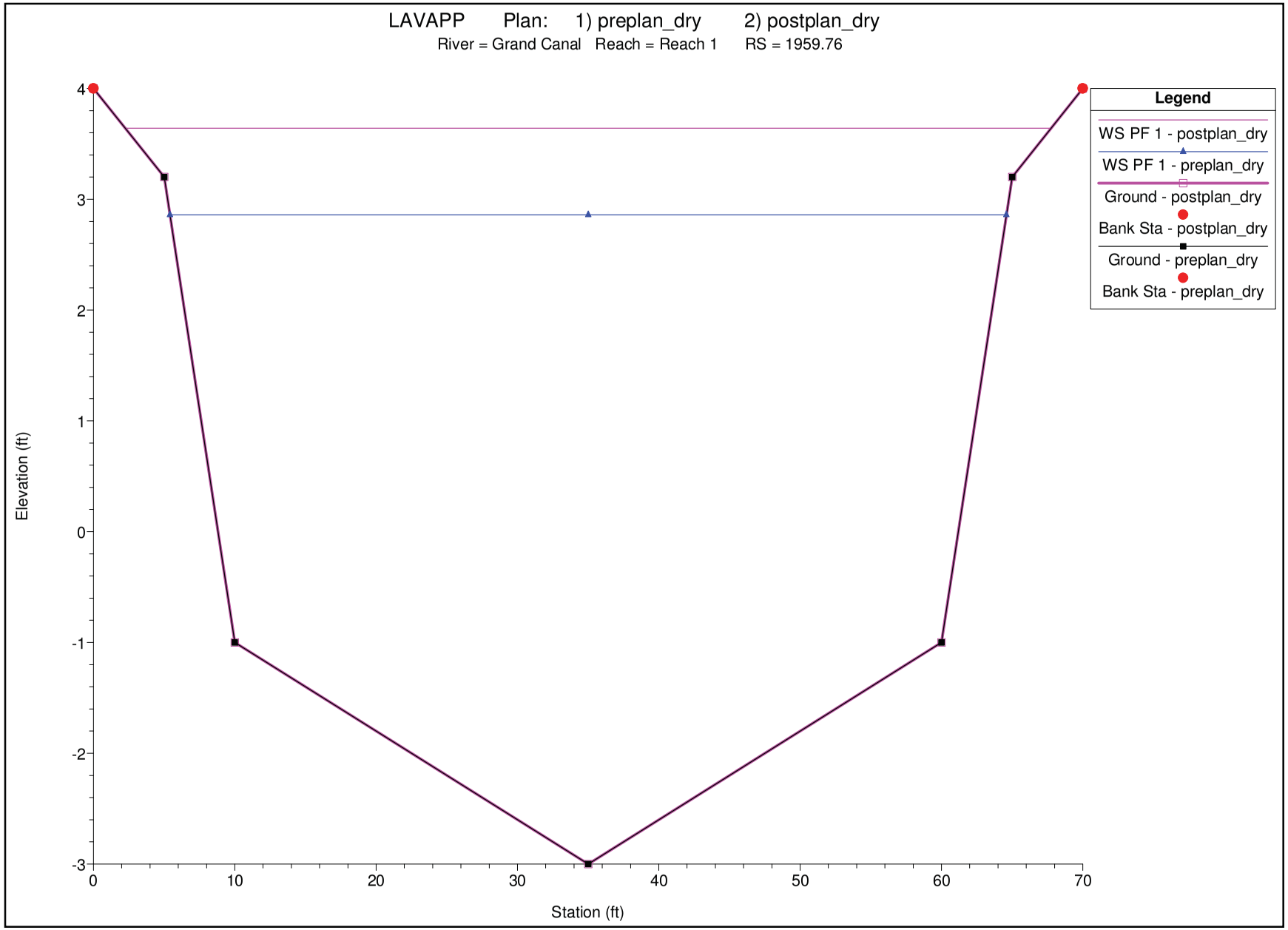
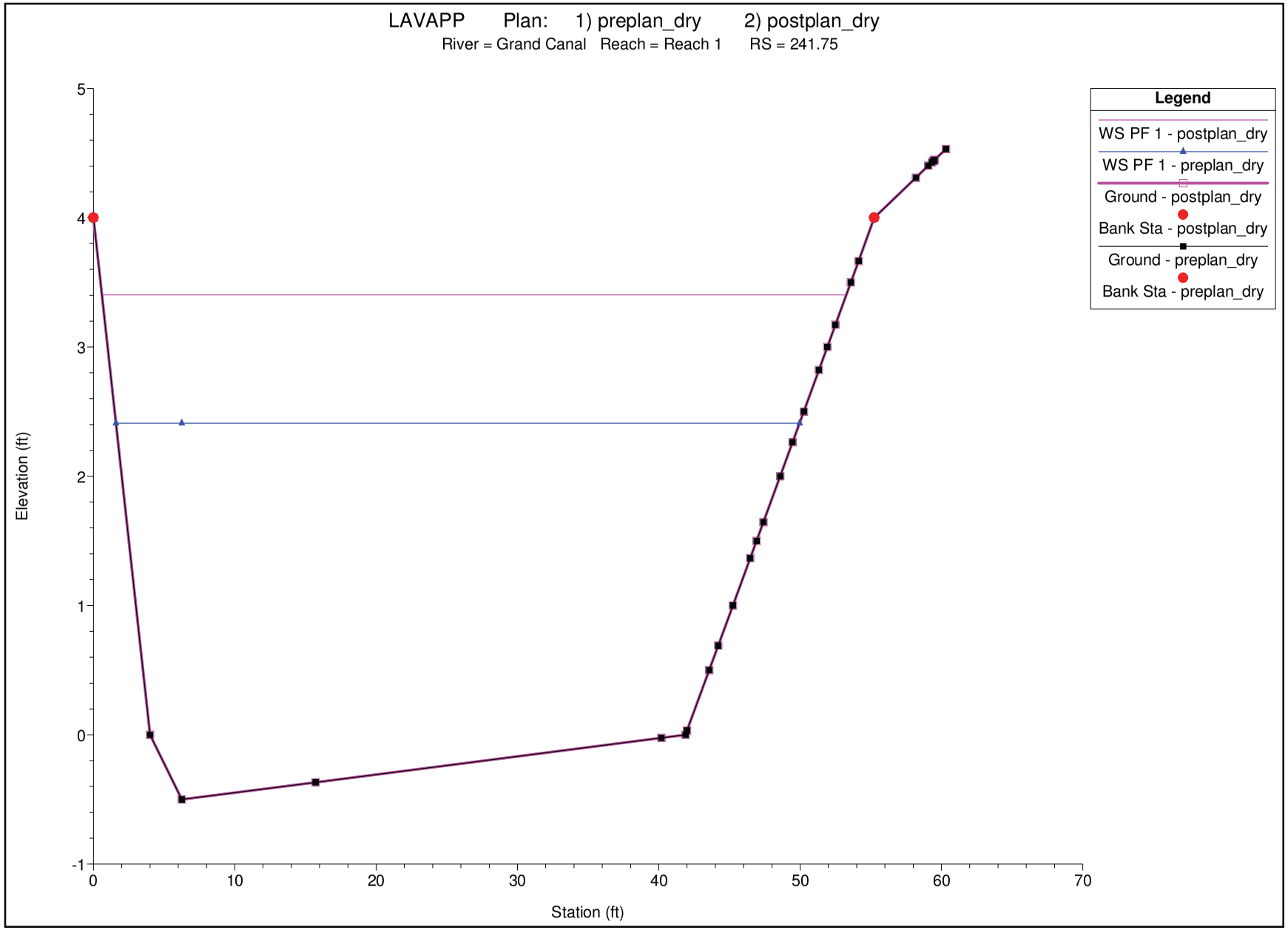
APPENDIX I
HYDRAULIC RESULTS

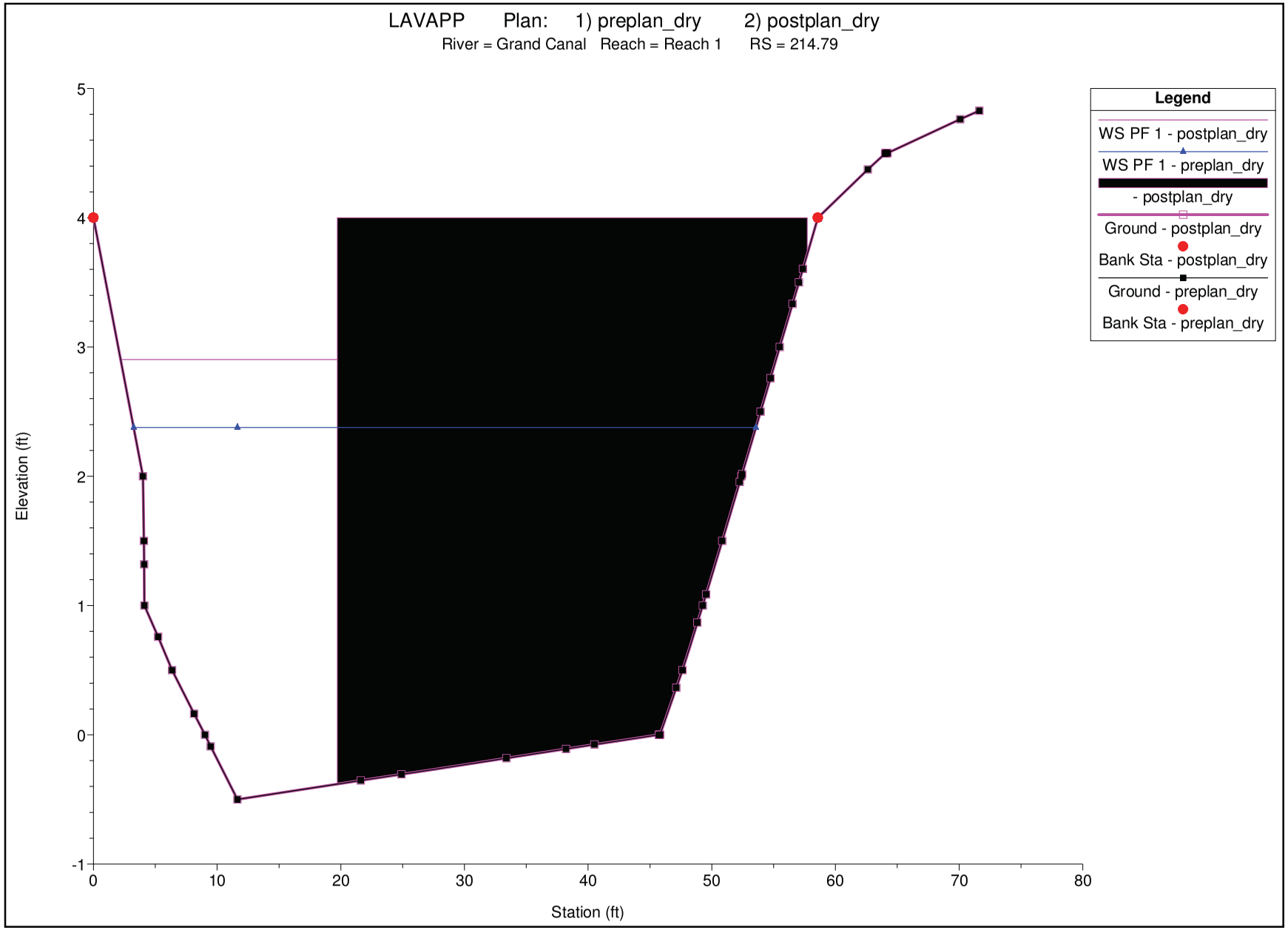
HEC-RAS River: Grand Canal Reach: Reach 1 Profile: PF 1

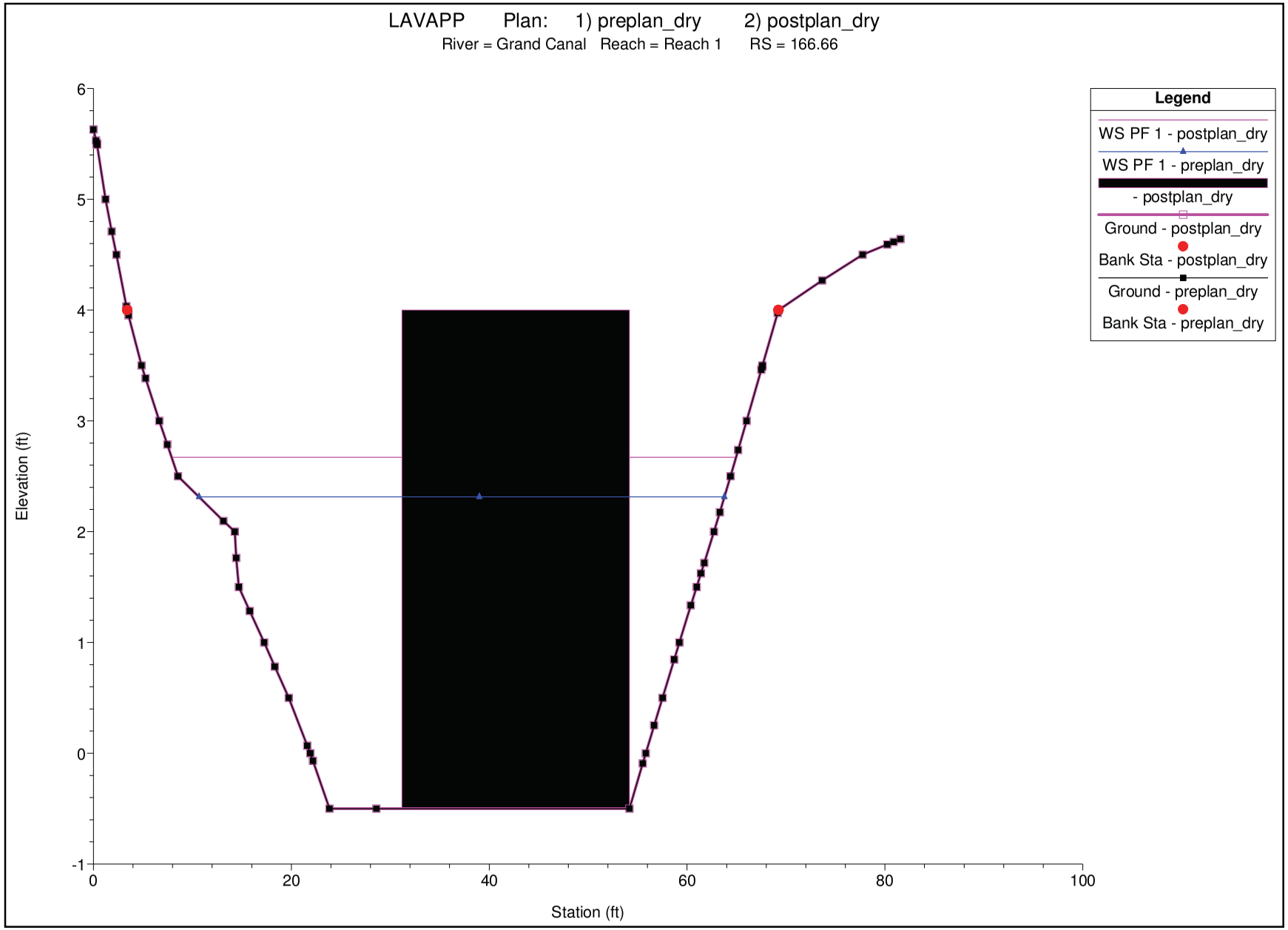
Reach	River Sta	Profile	Plan	Q Total	Min Ch El	W.S. Elev	Crit W.S.	E.G. Elev	E.G. Slope	Vel Chnl	Flow Area	Top Width	Froude # Chl
				(cfs)	(ft)	(ft)	(ft)	(ft)	(ft/ft)	(ft/s)	(sq ft)	(ft)	
Reach 1	1959.76	PF 1	preplan_extreme	263.80	-0.50	3.39		3.43	0.000442	1.62	162.92	52.62	0.16
Reach 1	1959.76	PF 1	postplan_extreme	263.80	-3.00	3.63		3.64	0.000072	0.86	307.86	65.36	0.07
Reach 1	1959.76	PF 1	postplan_ex_wet	263.80	-3.00	3.65		3.66	0.000071	0.85	309.14	65.60	0.07
Reach 1	1959.76	PF 1	postplan_ex_dry	263.80	-3.00	3.64		3.65	0.000072	0.85	308.61	65.50	0.07
Reach 1	1959.76	PF 1	preplan_wet	263.80	-0.50	3.35		3.40	0.000457	1.64	161.05	52.46	0.16
Reach 1	1959.76	PF 1	preplan_dry	263.80	-0.50	3.43		3.47	0.000424	1.60	165.23	52.81	0.16
Reach 1	1959.76	PF 1	pre_dry_no_flows	0.01	-0.50	2.10		2.10	0.000000	0.00	98.62	47.02	0.00
Reach 1	1959.76	PF 1	post_dry_no_flow	0.01	-3.00	2.10		2.10	0.000000	0.00	216.44	57.38	0.00
Reach 1	241.75	PF 1	preplan_extreme	263.80	-0.50	2.24		2.34	0.001631	2.50	105.44	47.65	0.30
Reach 1	241.75	PF 1	postplan_extreme	263.80	-0.50	3.39		3.43	0.000443	1.62	162.83	52.61	0.16
Reach 1	241.75	PF 1	postplan_ex_wet	263.80	-0.50	3.41		3.45	0.000433	1.61	164.03	52.71	0.16
Reach 1	241.75	PF 1	postplan_ex_dry	263.80	-0.50	3.40		3.44	0.000437	1.61	163.54	52.67	0.16
Reach 1	241.75	PF 1	preplan_wet	263.80	-0.50	2.08		2.19	0.002057	2.70	97.70	46.94	0.33
Reach 1	241.75	PF 1	preplan_dry	263.80	-0.50	2.41		2.49	0.001307	2.33	113.42	48.37	0.27
Reach 1	241.75	PF 1	pre_dry_no_flows	0.01	-0.50	2.10		2.10	0.000000	0.00	98.62	47.02	0.00
Reach 1	241.75	PF 1	post_dry_no_flow	0.01	-0.50	2.10		2.10	0.000000	0.00	98.62	47.02	0.00
Reach 1	214.79	PF 1	preplan_extreme	263.80	-0.50	2.20		2.30	0.001637	2.47	106.94	49.43	0.30
Reach 1	214.79	PF 1	postplan_extreme	263.80	-0.50	2.88		3.36	0.007862	5.52	47.77	17.48	0.59
Reach 1	214.79	PF 1	postplan_ex_wet	263.80	-0.50	2.92		3.38	0.007574	5.45	48.41	17.56	0.58
Reach 1	214.79	PF 1	postplan_ex_dry	263.80	-0.50	2.90		3.37	0.007690	5.48	48.14	17.53	0.58
Reach 1	214.79	PF 1	preplan_wet	263.80	-0.50	2.02		2.14	0.002114	2.68	98.27	48.53	0.33
Reach 1	214.79	PF 1	preplan_dry	263.80	-0.50	2.38		2.46	0.001291	2.28	115.70	50.32	0.27
Reach 1	214.79	PF 1	pre_dry_no_flows	0.01	-0.50	2.10		2.10	0.000000	0.00	101.93	48.91	0.00
Reach 1	214.79	PF 1	post_dry_no_flow	0.01	-0.50	2.10		2.10	0.000000	0.00	34.71	15.92	0.00
Reach 1	166.66	PF 1	preplan_extreme	263.80	-0.50	2.12		2.22	0.001722	2.50	105.50	50.23	0.30
Reach 1	166.66	PF 1	postplan_extreme	263.80	-0.50	2.63		2.92	0.007939	4.32	61.07	33.76	0.57
Reach 1	166.66	PF 1	postplan_ex_wet	263.80	-0.50	2.70		2.97	0.007153	4.16	63.41	34.25	0.54
Reach 1	166.66	PF 1	postplan_ex_dry	263.80	-0.50	2.67		2.95	0.007454	4.22	62.47	34.05	0.55
Reach 1	166.66	PF 1	preplan_wet	263.80	-0.50	1.91		2.03	0.002265	2.76	95.45	48.07	0.35
Reach 1	166.66	PF 1	preplan_dry	263.80	-0.50	2.31		2.39	0.001368	2.28	115.58	53.10	0.27
Reach 1	166.66	PF 1	pre_dry_no_flows	0.01	-0.50	2.10		2.10	0.000000	0.00	104.58	49.96	0.00
Reach 1	166.66	PF 1	post_dry_no_flow	0.01	-0.50	2.10		2.10	0.000000	0.00	44.78	26.96	0.00
Reach 1	127.09	PF 1	preplan_extreme	263.80	-1.00	2.06		2.15	0.001500	2.33	113.39	53.84	0.28
Reach 1	127.09	PF 1	postplan_extreme	263.80	-1.00	2.16		2.54	0.011427	4.94	53.35	31.43	0.67
Reach 1	127.09	PF 1	postplan_ex_wet	263.80	-1.00	2.36	1.60	2.66	0.008302	4.41	59.76	32.70	0.58
Reach 1	127.09	PF 1	postplan_ex_dry	263.80	-1.00	2.29		2.62	0.009197	4.58	57.63	32.28	0.60
Reach 1	127.09	PF 1	preplan_wet	263.80	-1.00	1.84		1.94	0.002028	2.60	101.46	51.11	0.33
Reach 1	127.09	PF 1	preplan_dry	263.80	-1.00	2.27		2.34	0.001128	2.11	124.74	55.16	0.25
Reach 1	127.09	PF 1	pre_dry_no_flows	0.01	-1.00	2.10		2.10	0.000000	0.00	115.32	54.07	0.00
Reach 1	127.09	PF 1	post_dry_no_flow	0.01	-1.00	2.10		2.10	0.000000	0.00	51.57	31.07	0.00
Reach 1	37.75	PF 1	preplan_extreme	263.80	-0.50	1.80	0.93	1.95	0.003525	3.06	86.09	52.00	0.42
Reach 1	37.75	PF 1	postplan_extreme	263.80	-0.50	1.80	0.93	1.95	0.003525	3.06	86.09	52.00	0.42
Reach 1	37.75	PF 1	postplan_ex_wet	263.80	-0.50	0.93	0.93	1.47	0.023641	5.88	44.83	42.51	1.01
Reach 1	37.75	PF 1	postplan_ex_dry	263.80	-0.50	2.10	0.93	2.20	0.002123	2.58	102.10	54.38	0.33
Reach 1	37.75	PF 1	preplan_wet	263.80	-0.50	0.93	0.93	1.47	0.023641	5.88	44.83	42.51	1.01
Reach 1	37.75	PF 1	preplan_dry	263.80	-0.50	2.10	0.93	2.20	0.002123	2.58	102.10	54.38	0.33
Reach 1	37.75	PF 1	pre_dry_no_flows	0.01	-0.50	2.10	-0.48	2.10	0.000000	0.00	102.10	54.38	0.00
Reach 1	37.75	PF 1	post_dry_no_flow	0.01	-0.50	2.10	-0.48	2.10	0.000000	0.00	102.10	54.38	0.00

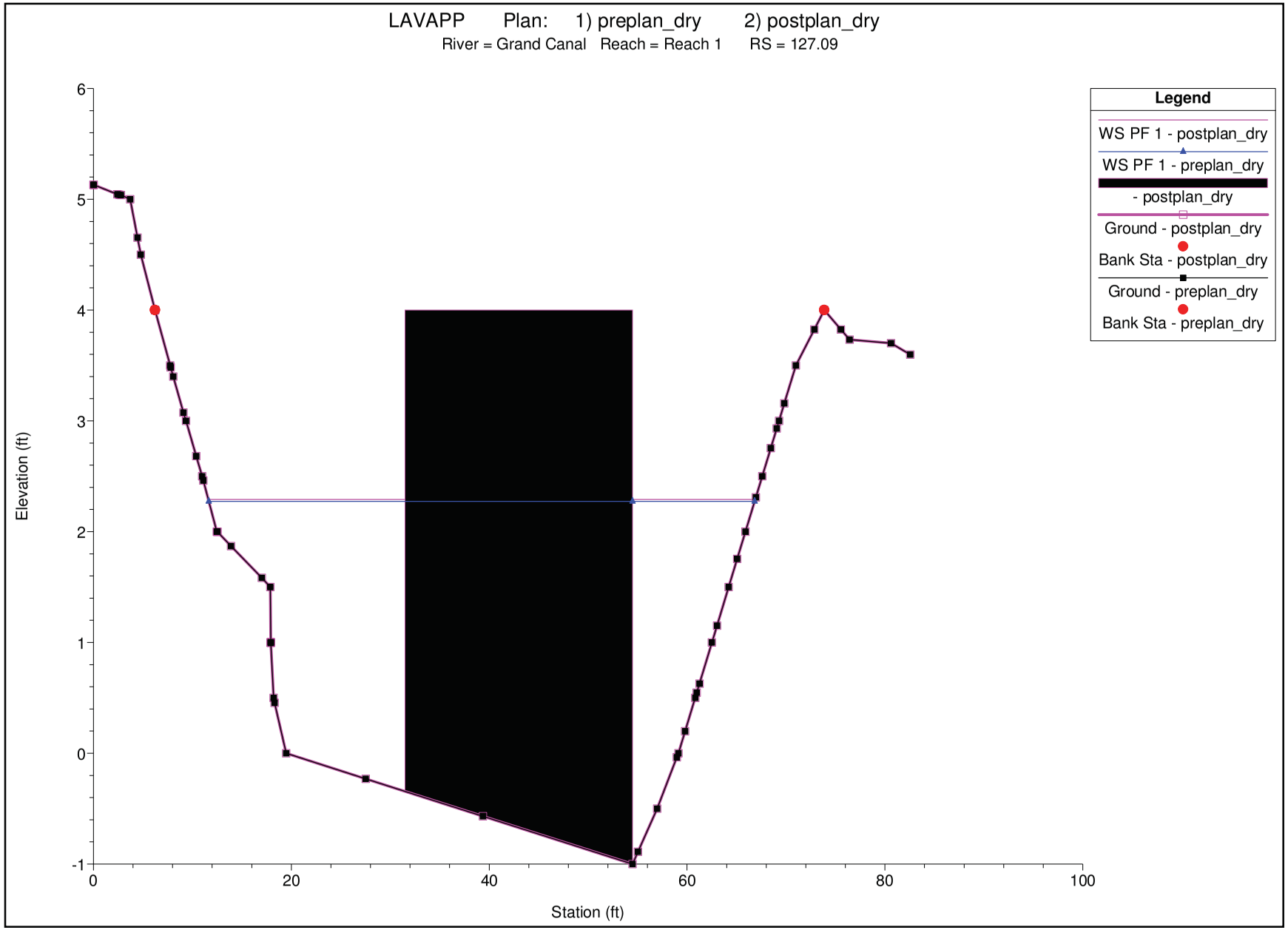
APPENDIX J
HEC-RAS CROSS SECTIONS OF GRAND CANAL

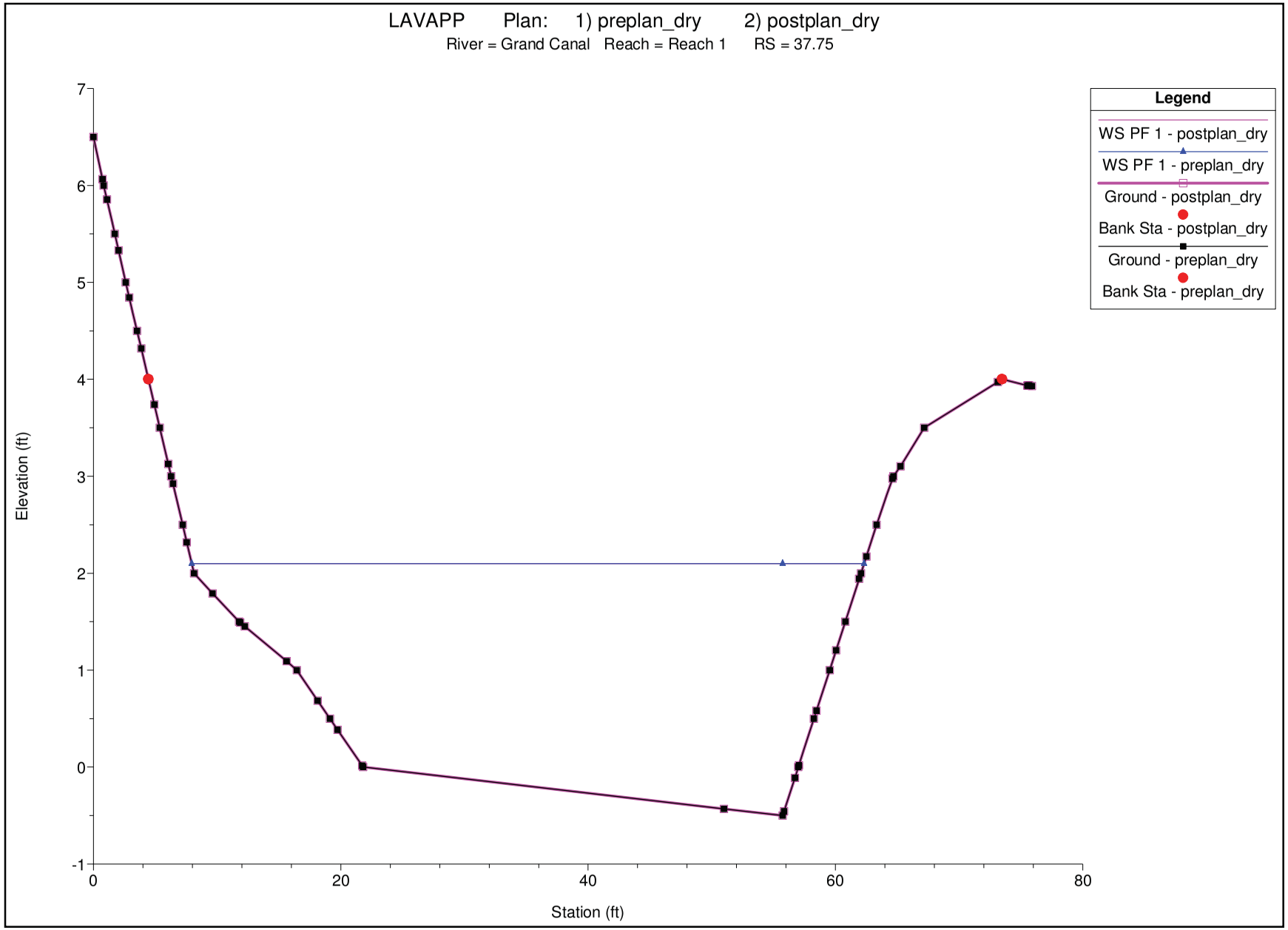

LAVAPP Plan: 1) preplan_dry 2) postplan_dry
River = Grand Canal Reach = Reach 1 RS = 1959.76
Legend
WS PF 1 - postplan_dry
WS PF 1 - preplan_dry
Ground - postplan_dry
Bank Sta - postplan_dry
Ground - preplan_dry
Bank Sta - preplan_dry
Elevation (ft)
Station (ft)
4
3
2
1
0
-1
-2
-3
0
10
20
30
40
50
60
70

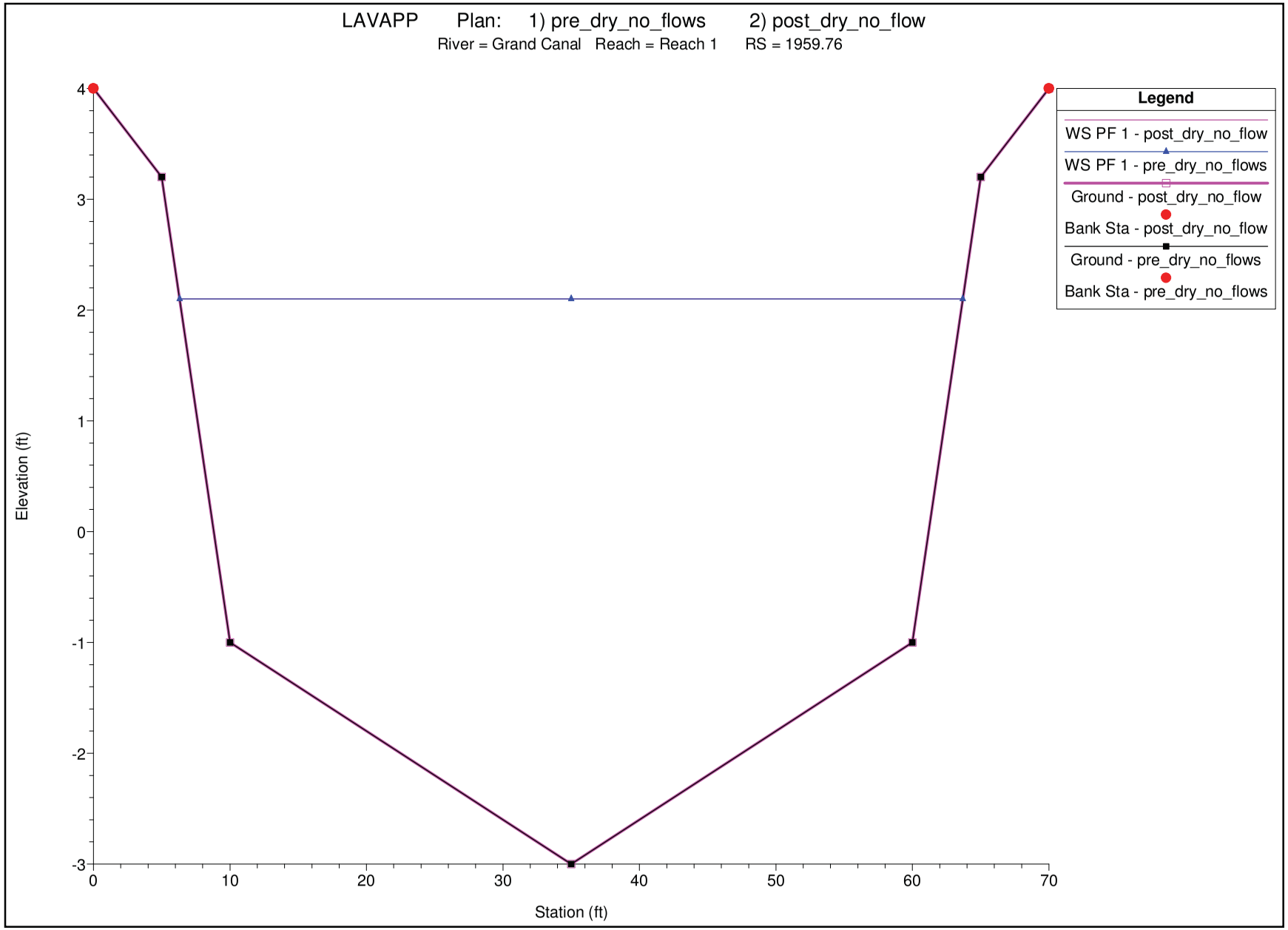

LAVAPP Plan: 1) preplan_dry 2) postplan_dry
River = Grand Canal Reach = Reach 1 RS = 241.75
Legend
WS PF 1 - postplan_dry
WS PF 1 - preplan_dry
Ground - postplan_dry
Bank Sta - postplan_dry
Ground - preplan_dry
Bank Sta - preplan_dry
Elevation (ft)
Station (ft)
5
4
3
2
1
0
-1
0
10
20
30
40
50
60
70

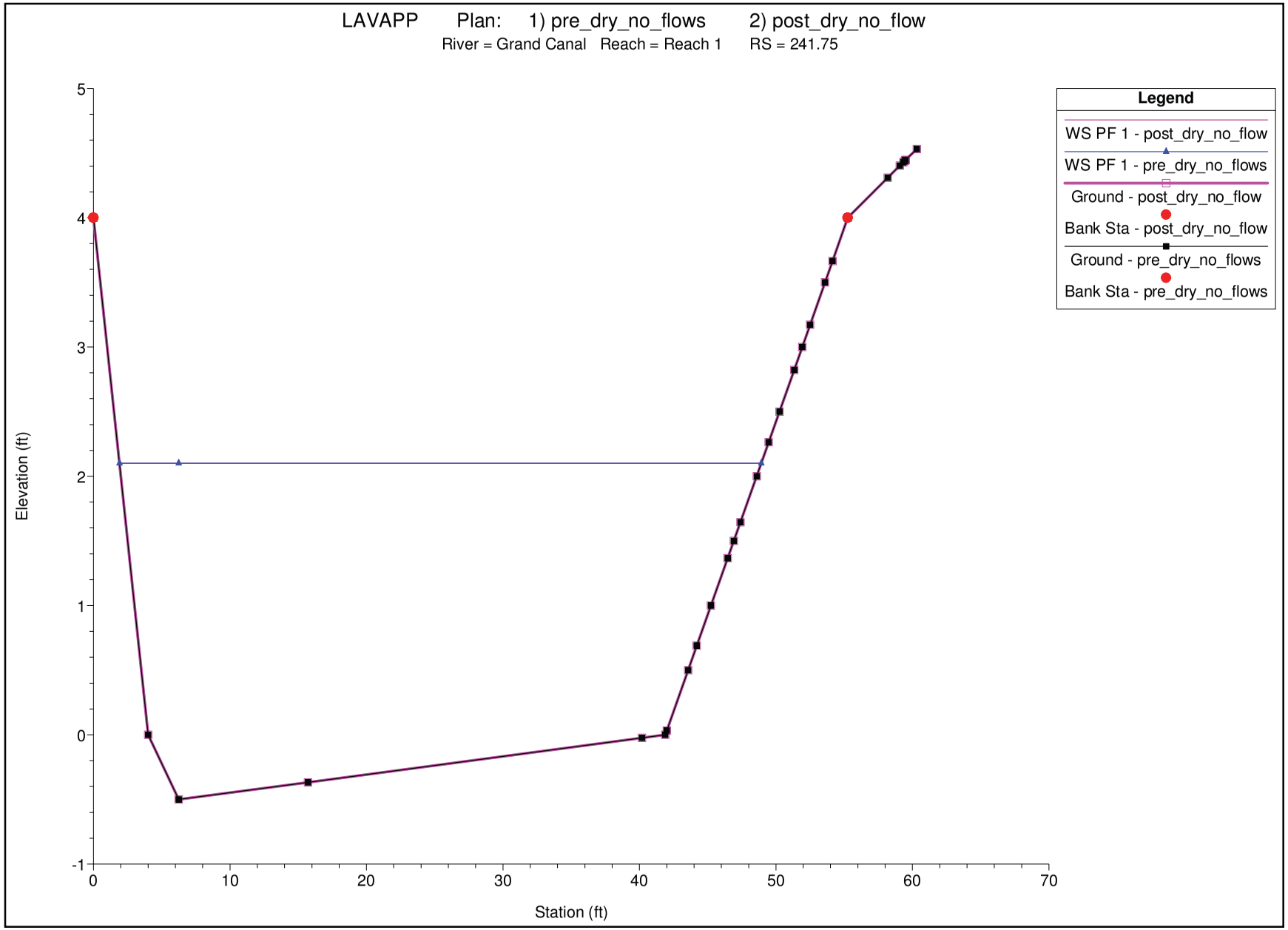

LAVAPP Plan: 1) preplan_dry 2) postplan_dry
River = Grand Canal Reach = Reach 1 RS = 214.79
Legend
WS PF 1 - postplan_dry
WS PF 1 - preplan_dry
- postplan_dry
Ground - postplan_dry
Bank Sta - postplan_dry
Ground - preplan_dry
Bank Sta - preplan_dry
Elevation (ft)
Station (ft)
5
4
3
2
1
0
-1
0
10
20
30
40
50
60
70
80

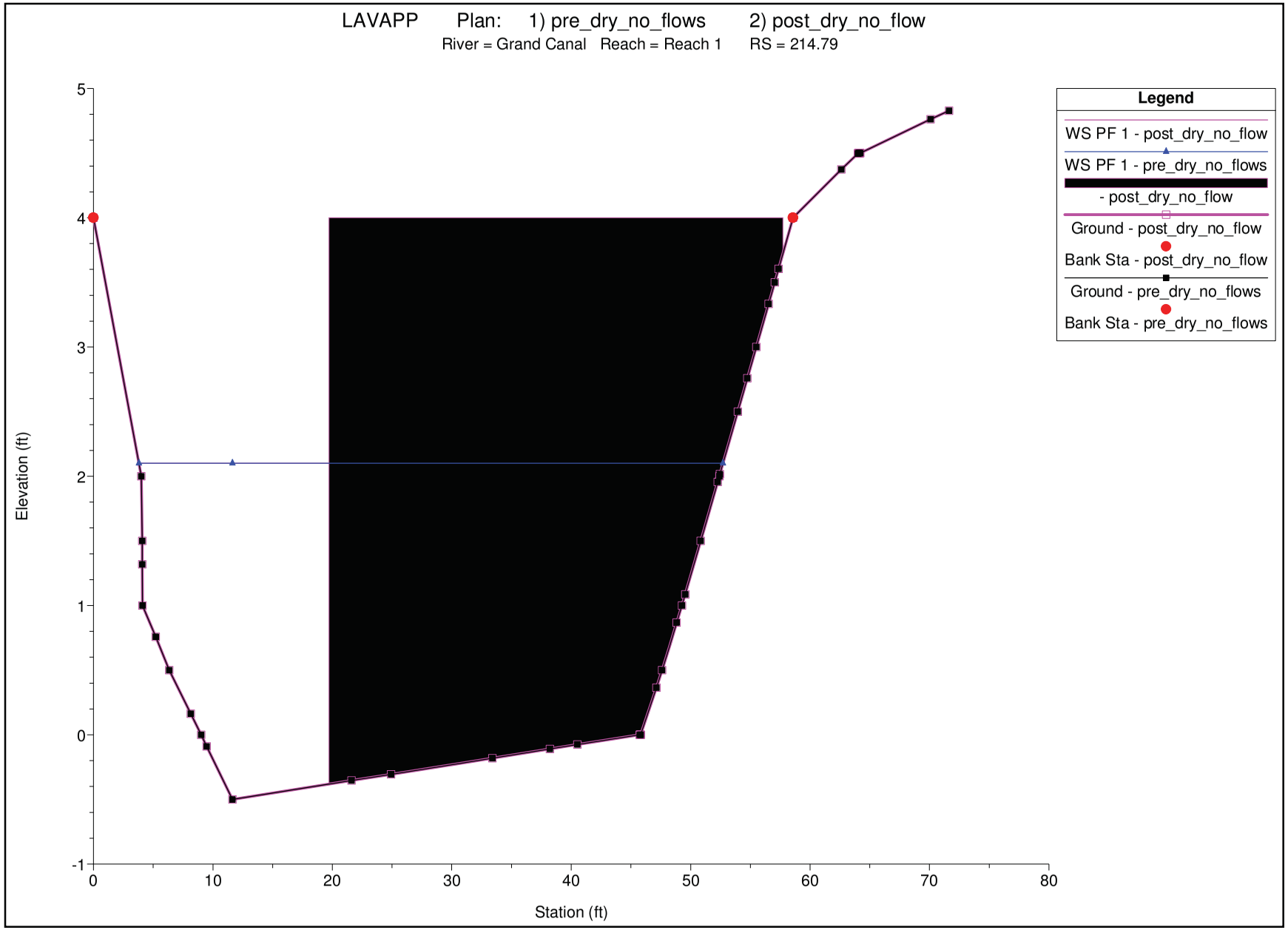

LAVAPP Plan: 1) preplan_dry 2) postplan_dry
River = Grand Canal Reach = Reach 1 RS = 166.66
Legend
WS PF 1 - postplan_dry
WS PF 1 - preplan_dry
- postplan_dry
Ground - postplan_dry
Bank Sta - postplan_dry
Ground - preplan_dry
Bank Sta - preplan_dry
Elevation (ft)
Station (ft)
6
5
4
3
2
1
0
-1
0
20
40
60
80
100

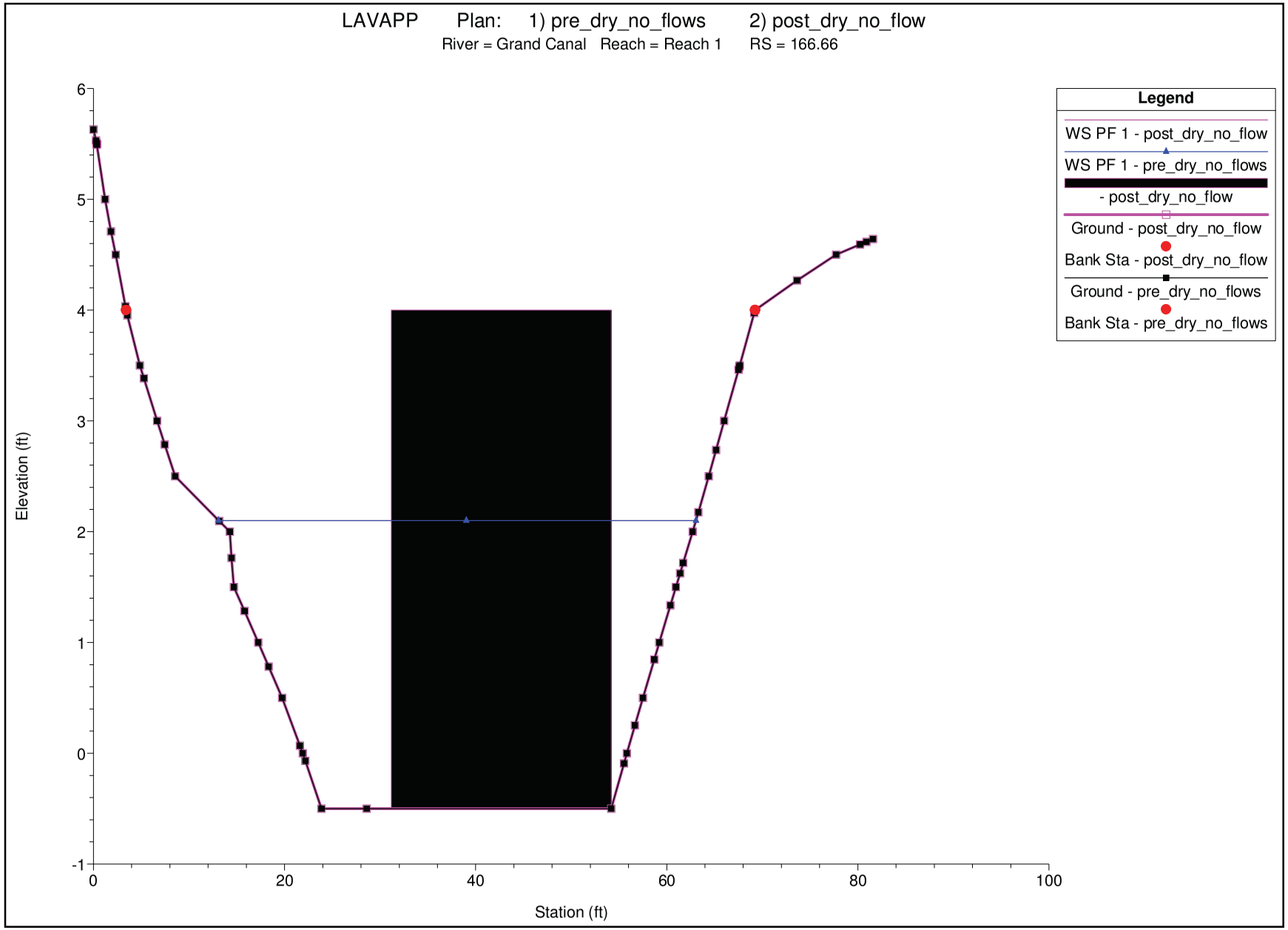

LAVAPP Plan: 1) preplan_dry 2) postplan_dry
River = Grand Canal Reach = Reach 1 RS = 127.09
Legend
WS PF 1 - postplan_dry
WS PF 1 - preplan_dry
- postplan_dry
Ground - postplan_dry
Bank Sta - postplan_dry
Ground - preplan_dry
Bank Sta - preplan_dry
Elevation (ft)
Station (ft)
6
5
4
3
2
1
0
-1
0
20
40
60
80
100

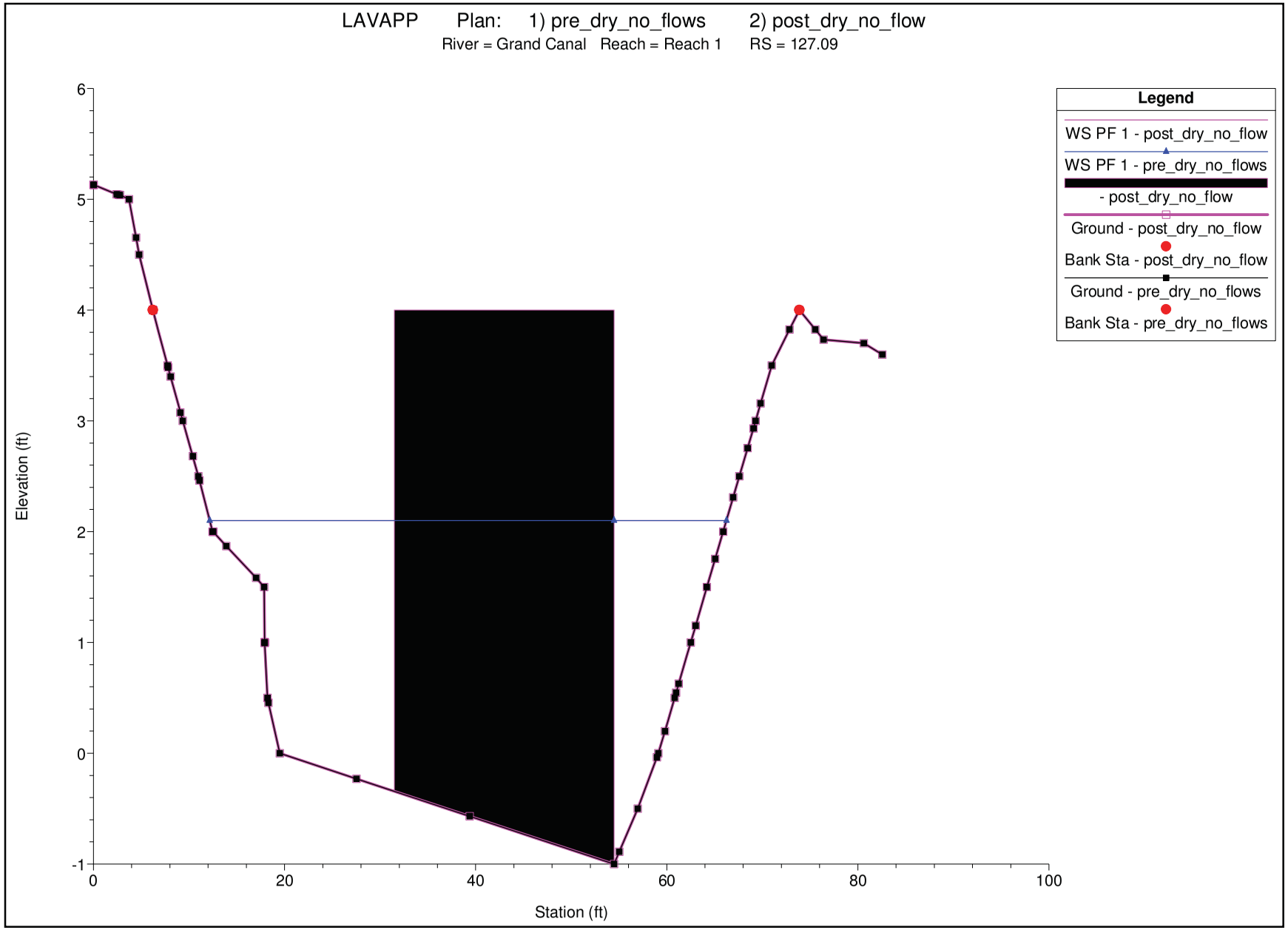

LAVAPP Plan: 1) preplan_dry 2) postplan_dry
River = Grand Canal Reach = Reach 1 RS = 37.75
Legend
WS PF 1 - postplan_dry
WS PF 1 - preplan_dry
Ground - postplan_dry
Bank Sta - postplan_dry
Ground - preplan_dry
Bank Sta - preplan_dry
Elevation (ft)
Station (ft)
7
6
5
4
3
2
1
0
-1
0
20
40
60
80

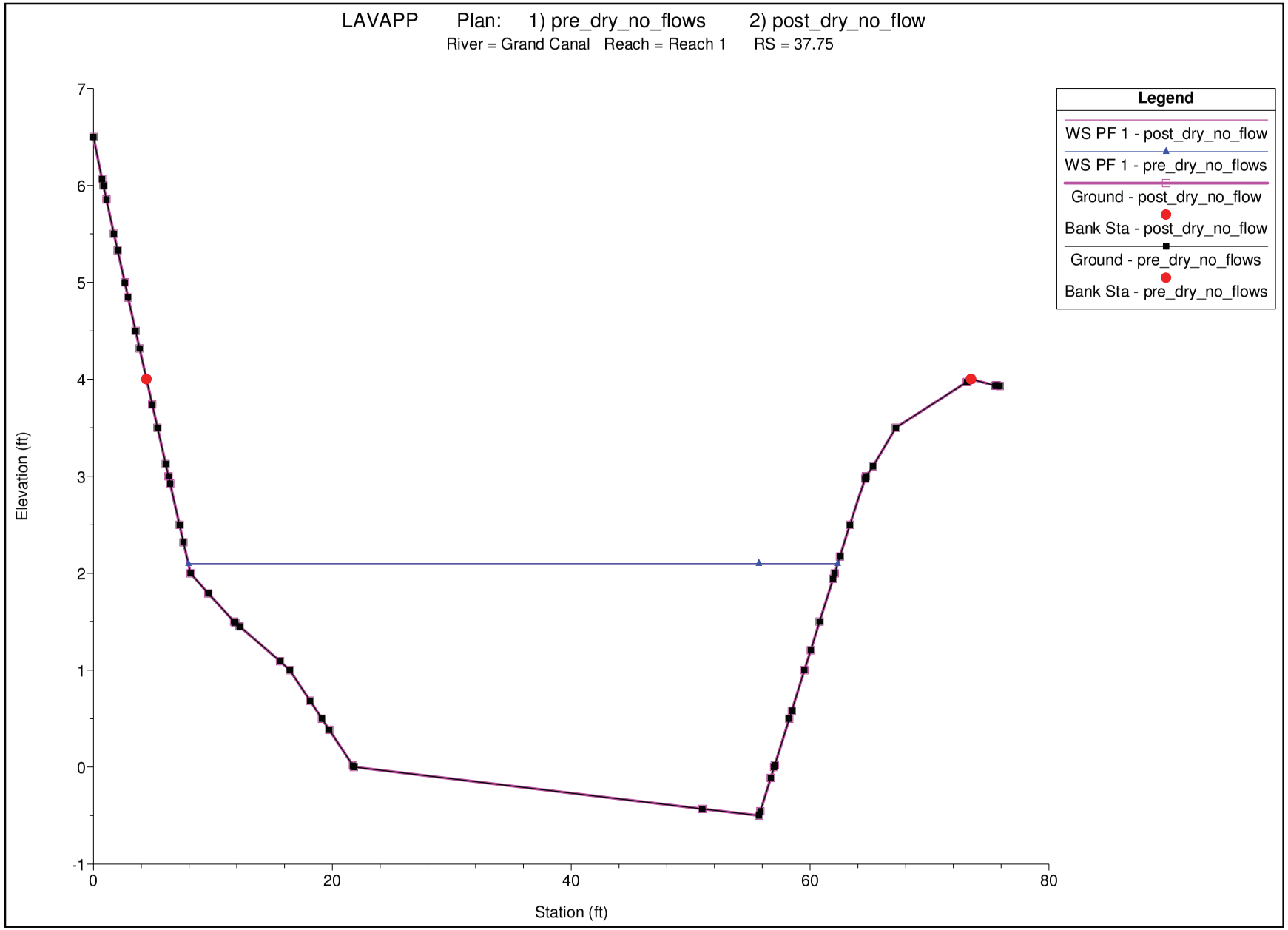

LAVAPP Plan: 1) pre_dry_no_flows 2) post_dry_no_flow
River = Grand Canal Reach = Reach 1 RS = 1959.76
Legend
WS PF 1 - post_dry_no_flow
WS PF 1 - pre_dry_no_flows
Ground - post_dry_no_flow
Bank Sta - post_dry_no_flow
Ground - pre_dry_no_flows
Bank Sta - pre_dry_no_flows
Elevation (ft)
Station (ft)
4
3
2
1
0
-1
-2
-3
0
10
20
30
40
50
60
70

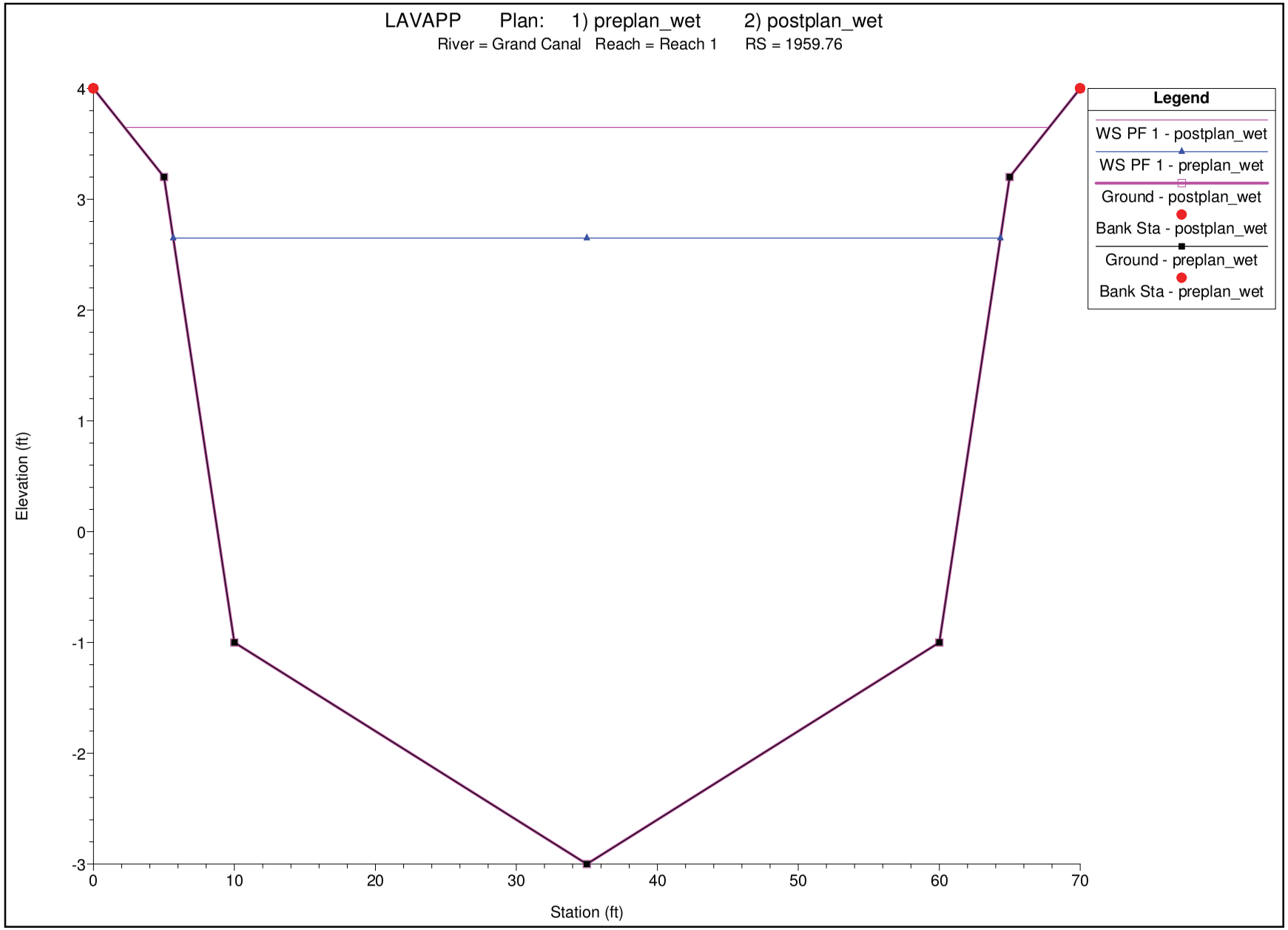

LAVAPP Plan: 1) pre_dry_no_flows 2) post_dry_no_flow
River = Grand Canal Reach = Reach 1 RS = 241.75
Legend
WS PF 1 - post_dry_no_flow
WS PF 1 - pre_dry_no_flows
Ground - post_dry_no_flow
Bank Sta - post_dry_no_flow
Ground - pre_dry_no_flows
Bank Sta - pre_dry_no_flows
Elevation (ft)
Station (ft)
5
4
3
2
1
0
-1
0
10
20
30
40
50
60
70

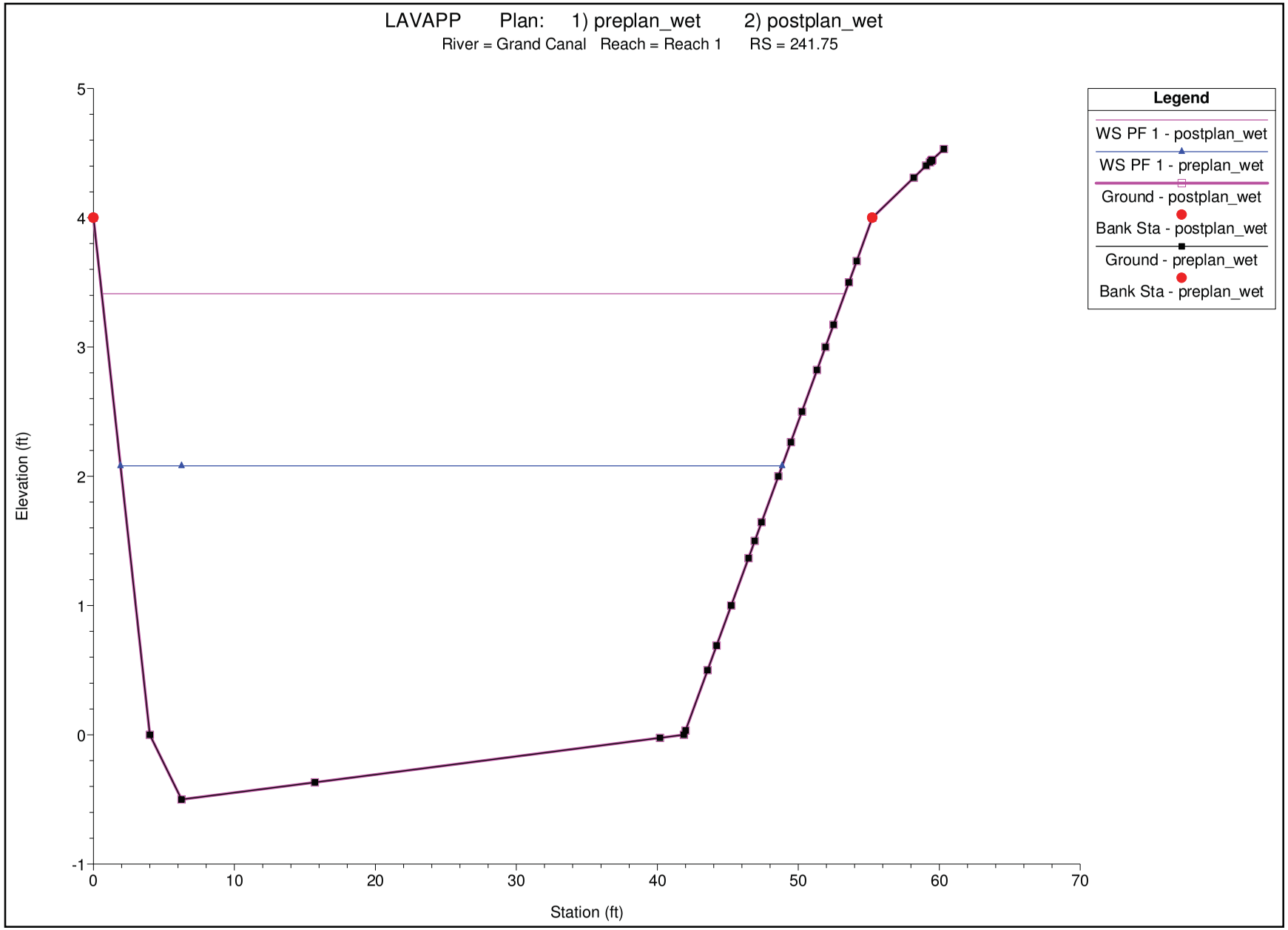

LAVAPP Plan: 1) pre_dry_no_flows 2) post_dry_no_flow
River = Grand Canal Reach = Reach 1 RS = 214.79
Legend
WS PF 1 - post_dry_no_flow
WS PF 1 - pre_dry_no_flows
- post_dry_no_flow
Ground - post_dry_no_flow
Bank Sta - post_dry_no_flow
Ground - pre_dry_no_flows
Bank Sta - pre_dry_no_flows
Elevation (ft)
Station (ft)
5
4
3
2
1
0
-1
0
10
20
30
40
50
60
70
80

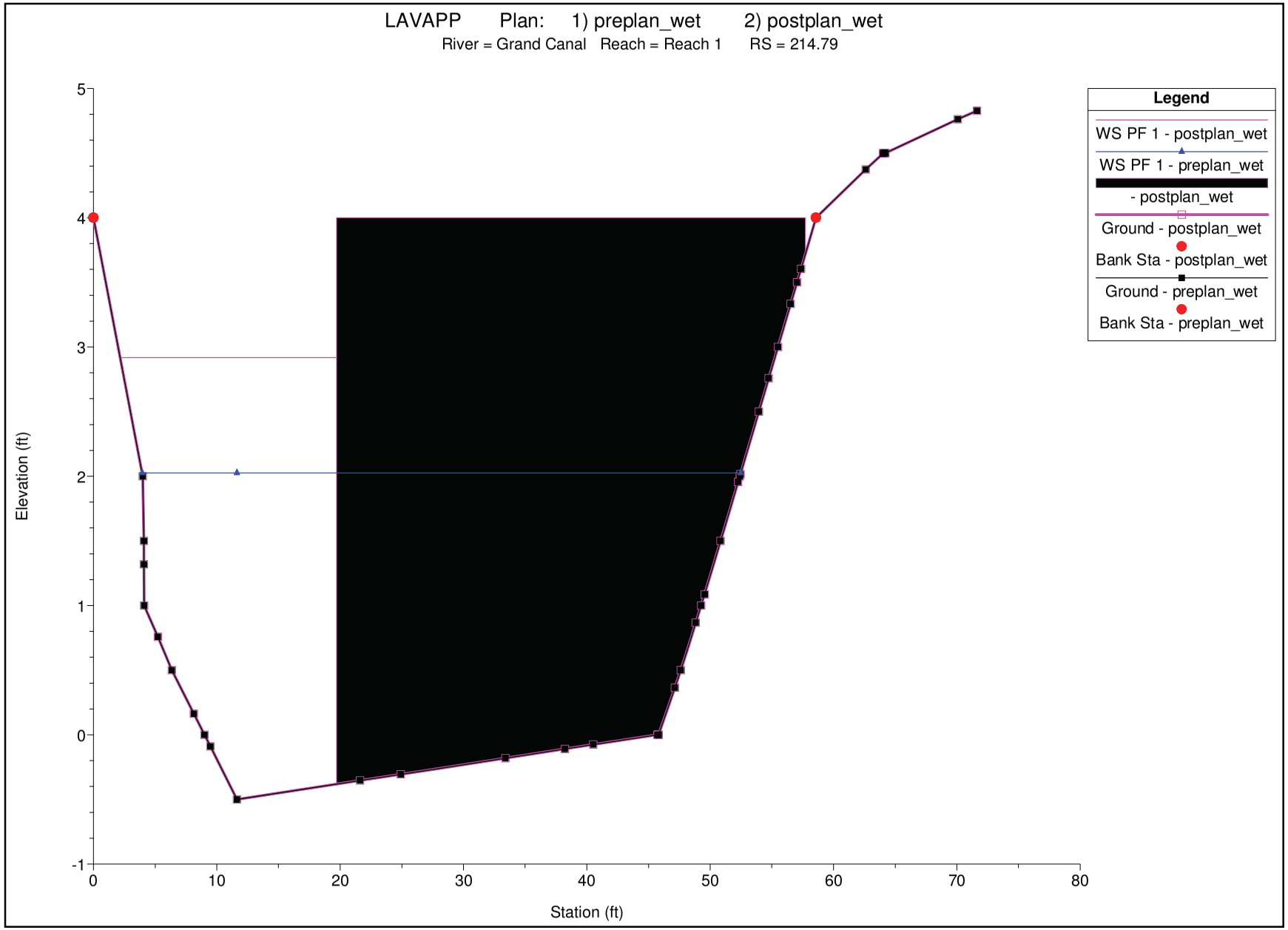

LAVAPP Plan: 1) pre_dry_no_flows 2) post_dry_no_flow
River = Grand Canal Reach = Reach 1 RS = 166.66
Legend
WS PF 1 - post_dry_no_flow
WS PF 1 - pre_dry_no_flows
- post_dry_no_flow
Ground - post_dry_no_flow
Bank Sta - post_dry_no_flow
Ground - pre_dry_no_flows
Bank Sta - pre_dry_no_flows
Elevation (ft)
Station (ft)
6
5
4
3
2
1
0
-1
0
20
40
60
80
100

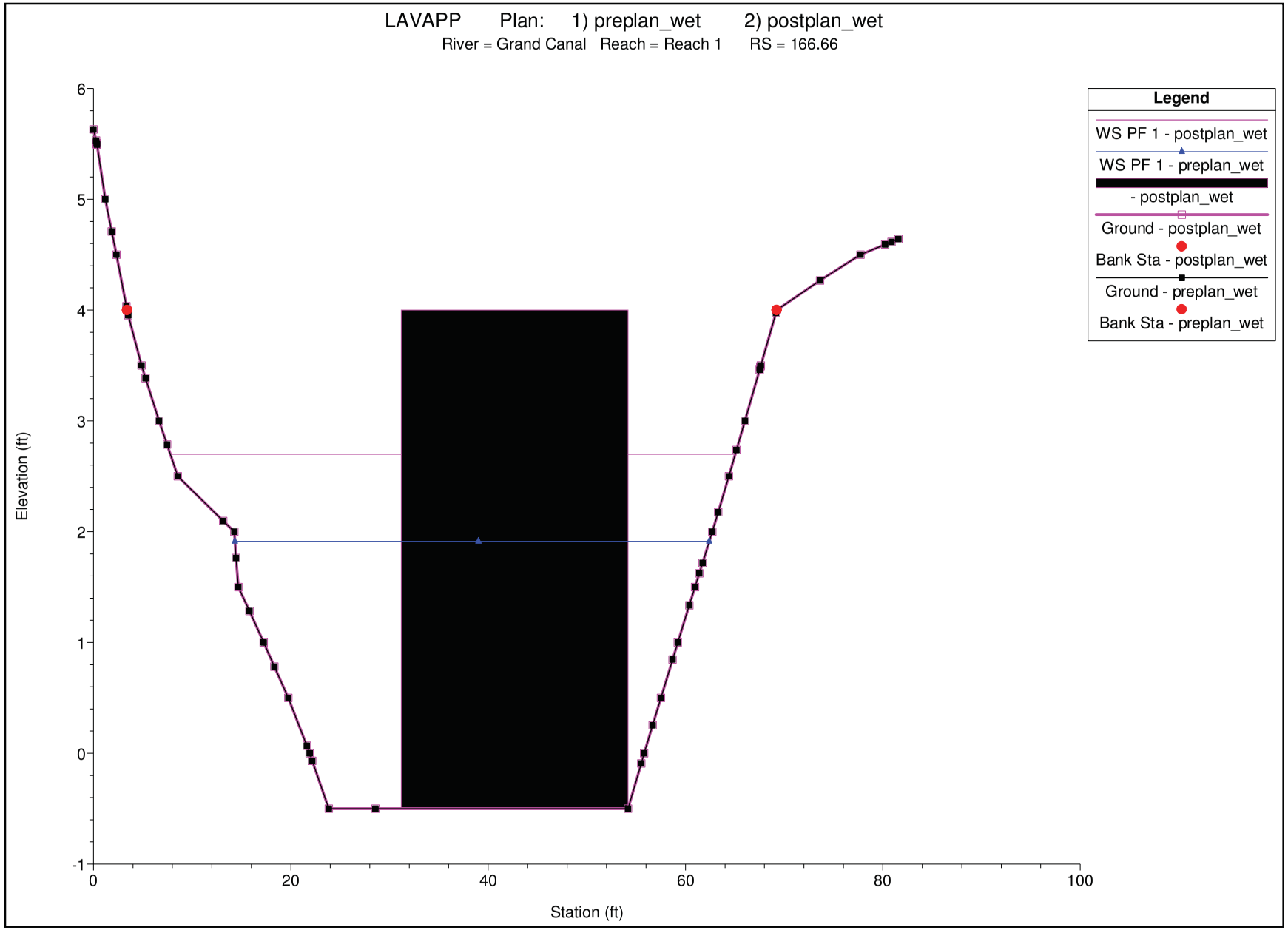

LAVAPP Plan: 1) pre_dry_no_flows 2) post_dry_no_flow
River = Grand Canal Reach = Reach 1 RS = 127.09
Legend
WS PF 1 - post_dry_no_flow
WS PF 1 - pre_dry_no_flows
- post_dry_no_flow
Ground - post_dry_no_flow
Bank Sta - post_dry_no_flow
Ground - pre_dry_no_flows
Bank Sta - pre_dry_no_flows
Elevation (ft)
Station (ft)
6
5
4
3
2
1
0
-1
0
20
40
60
80
100

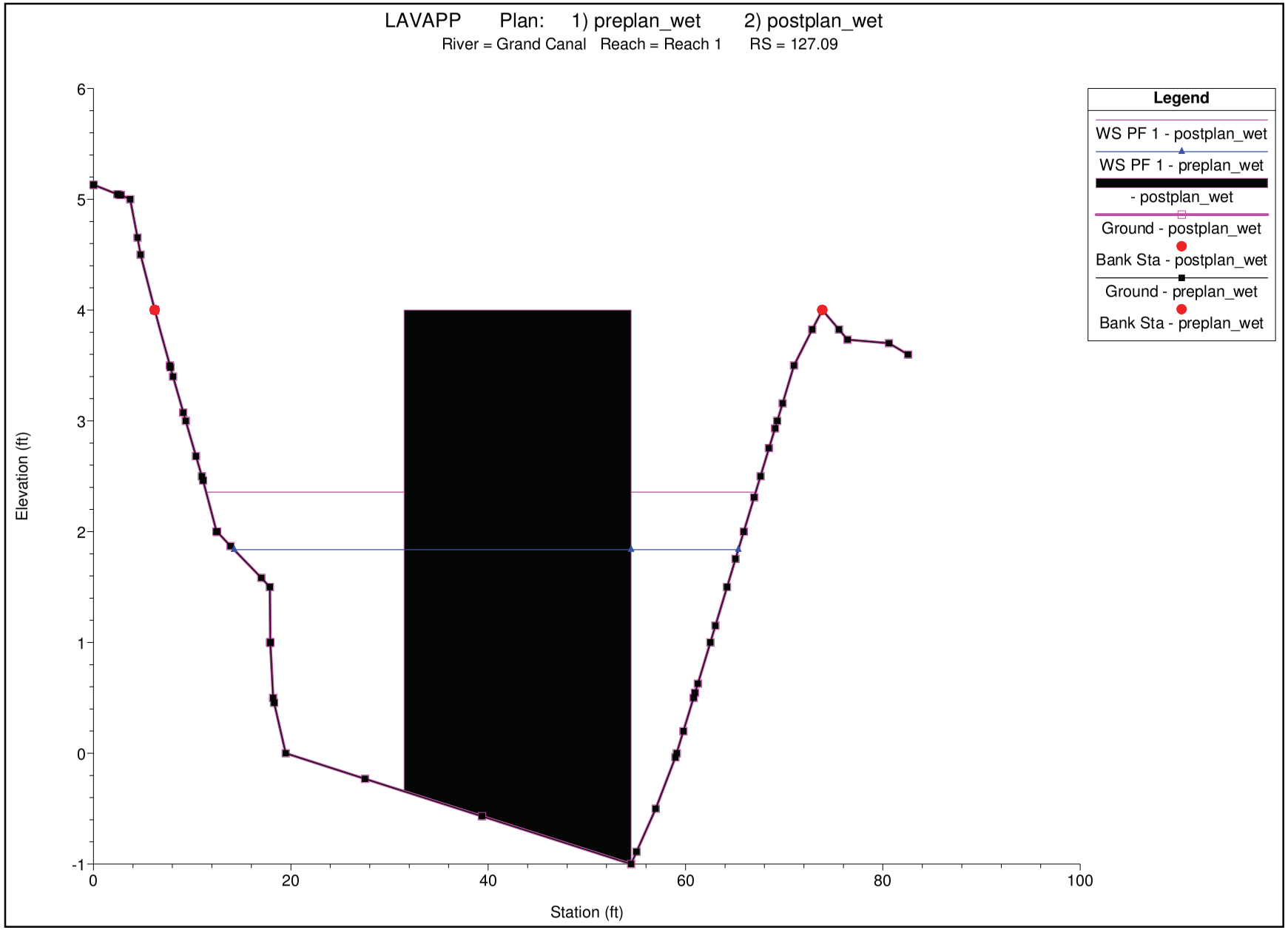

LAVAPP Plan: 1) pre_dry_no_flows 2) post_dry_no_flow
River = Grand Canal Reach = Reach 1 RS = 37.75
Legend
WS PF 1 - post_dry_no_flow
WS PF 1 - pre_dry_no_flows
Ground - post_dry_no_flow
Bank Sta - post_dry_no_flow
Ground - pre_dry_no_flows
Bank Sta - pre_dry_no_flows
Elevation (ft)
Station (ft)
7
6
5
4
3
2
1
0
-1
0
20
40
60
80

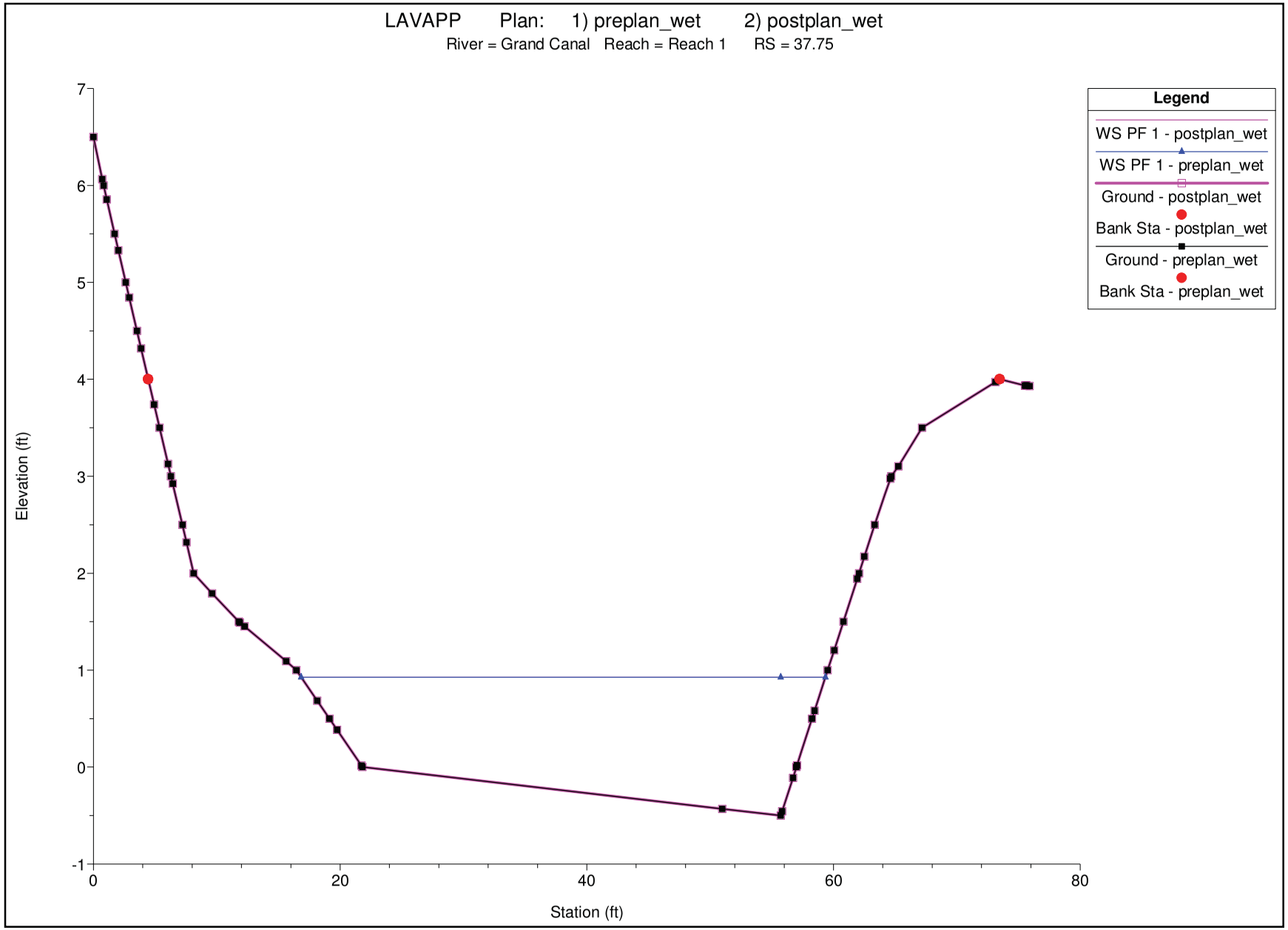

LAVAPP Plan: 1) preplan_wet 2) postplan_wet
River = Grand Canal Reach = Reach 1 RS = 1959.76
Legend
WS PF 1 - postplan_wet
WS PF 1 - preplan_wet
Ground - postplan_wet
Bank Sta - postplan_wet
Ground - preplan_wet
Bank Sta - preplan_wet
Elevation (ft)
Station (ft)
4
3
2
1
0
-1
-2
-3
0
10
20
30
40
50
60
70

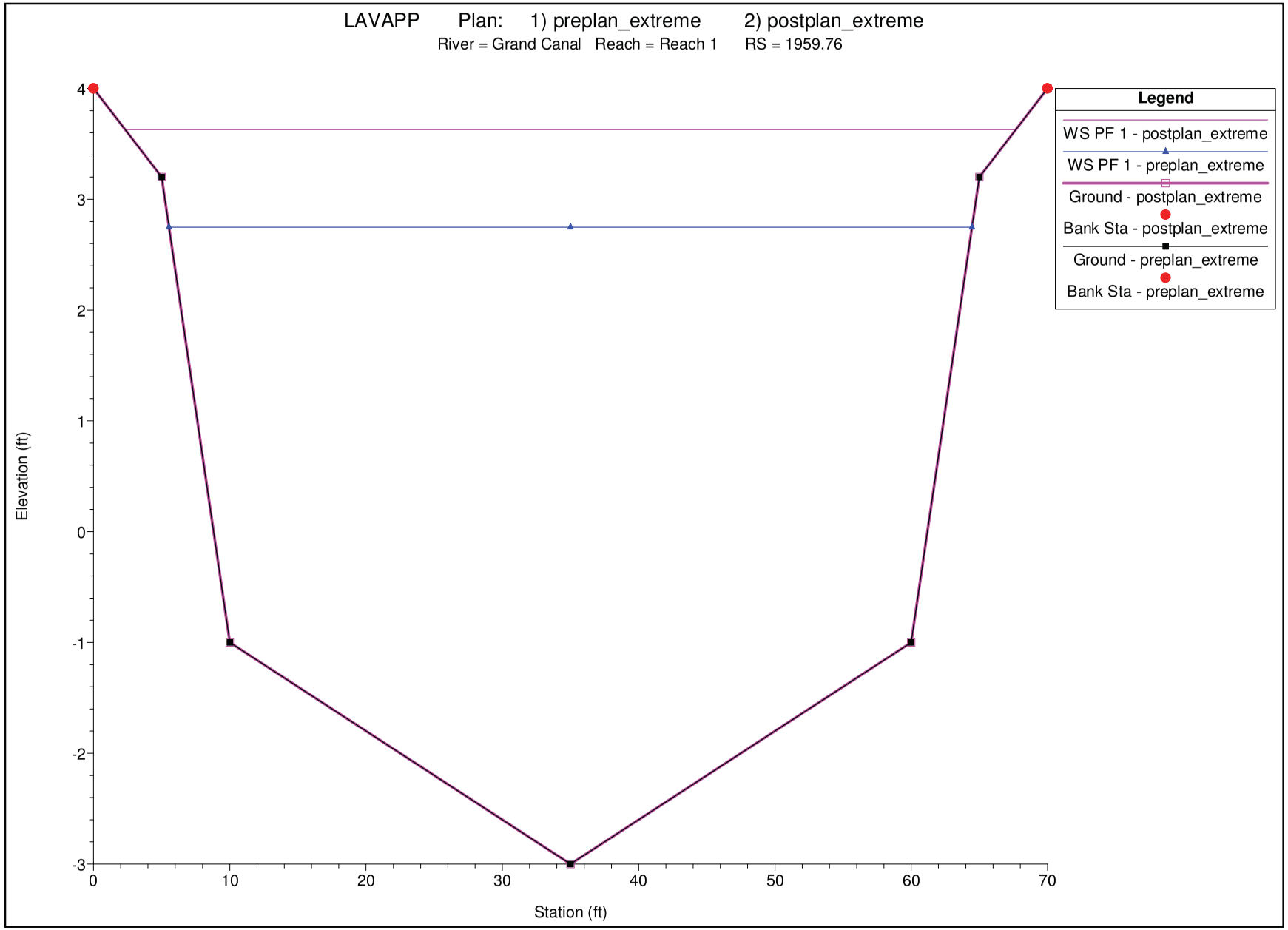

LAVAPP Plan: 1) preplan_wet 2) postplan_wet
River = Grand Canal Reach = Reach 1 RS = 241.75
Legend
WS PF 1 - postplan_wet
WS PF 1 - preplan_wet
Ground - postplan_wet
Bank Sta - postplan_wet
Ground - preplan_wet
Bank Sta - preplan_wet
Elevation (ft)
Station (ft)
5
4
3
2
1
0
-1
0
10
20
30
40
50
60
70


LAVAPP Plan: 1) preplan_wet 2) postplan_wet
River = Grand Canal Reach = Reach 1 RS = 214.79
Legend
WS PF 1 - postplan_wet
WS PF 1 - preplan_wet
- postplan_wet
Ground - postplan_wet
Bank Sta - postplan_wet
Ground - preplan_wet
Bank Sta - preplan_wet
Elevation (ft)
Station (ft)
5
4
3
2
1
0
-1
0
10
20
30
40
50
60
70
80


LAVAPP Plan: 1) preplan_wet 2) postplan_wet
River = Grand Canal Reach = Reach 1 RS = 166.66
Legend
WS PF 1 - postplan_wet
WS PF 1 - preplan_wet
- postplan_wet
Ground - postplan_wet
Bank Sta - postplan_wet
Ground - preplan_wet
Bank Sta - preplan_wet
Elevation (ft)
Station (ft)
6
5
4
3
2
1
0
-1
0
20
40
60
80
100


LAVAPP Plan: 1) preplan_wet 2) postplan_wet
River = Grand Canal Reach = Reach 1 RS = 127.09
Legend
WS PF 1 - postplan_wet
WS PF 1 - preplan_wet
- postplan_wet
Ground - postplan_wet
Bank Sta - postplan_wet
Ground - preplan_wet
Bank Sta - preplan_wet
Elevation (ft)
Station (ft)
6
5
4
3
2
1
0
-1
0
20
40
60
80
100


LAVAPP Plan: 1) preplan_wet 2) postplan_wet
River = Grand Canal Reach = Reach 1 RS = 37.75
Legend
WS PF 1 - postplan_wet
WS PF 1 - preplan_wet
Ground - postplan_wet
Bank Sta - postplan_wet
Ground - preplan_wet
Bank Sta - preplan_wet
Elevation (ft)
Station (ft)
7
6
5
4
3
2
1
0
-1
0
20
40
60
80


LAVAPP Plan: 1) preplan_extreme 2) postplan_extreme
River = Grand Canal Reach = Reach 1 RS = 1959.76
Legend
WS PF 1 - postplan_extreme
WS PF 1 - preplan_extreme
Ground - postplan_extreme
Bank Sta - postplan_extreme
Ground - preplan_extreme
Bank Sta - preplan_extreme
Elevation (ft)
Station (ft)
4
3
2
1
0
-1
-2
-3
0
10
20
30
40
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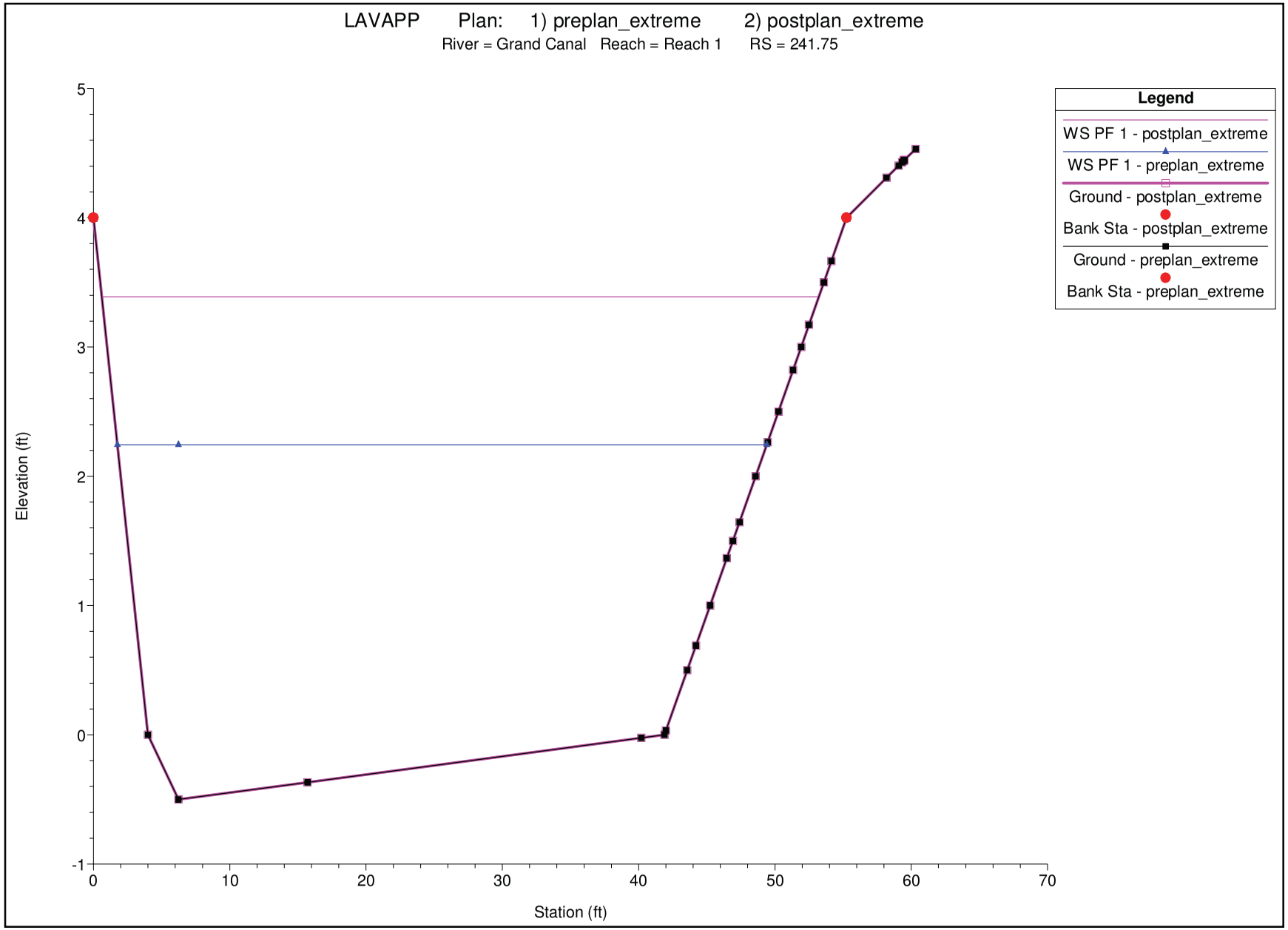
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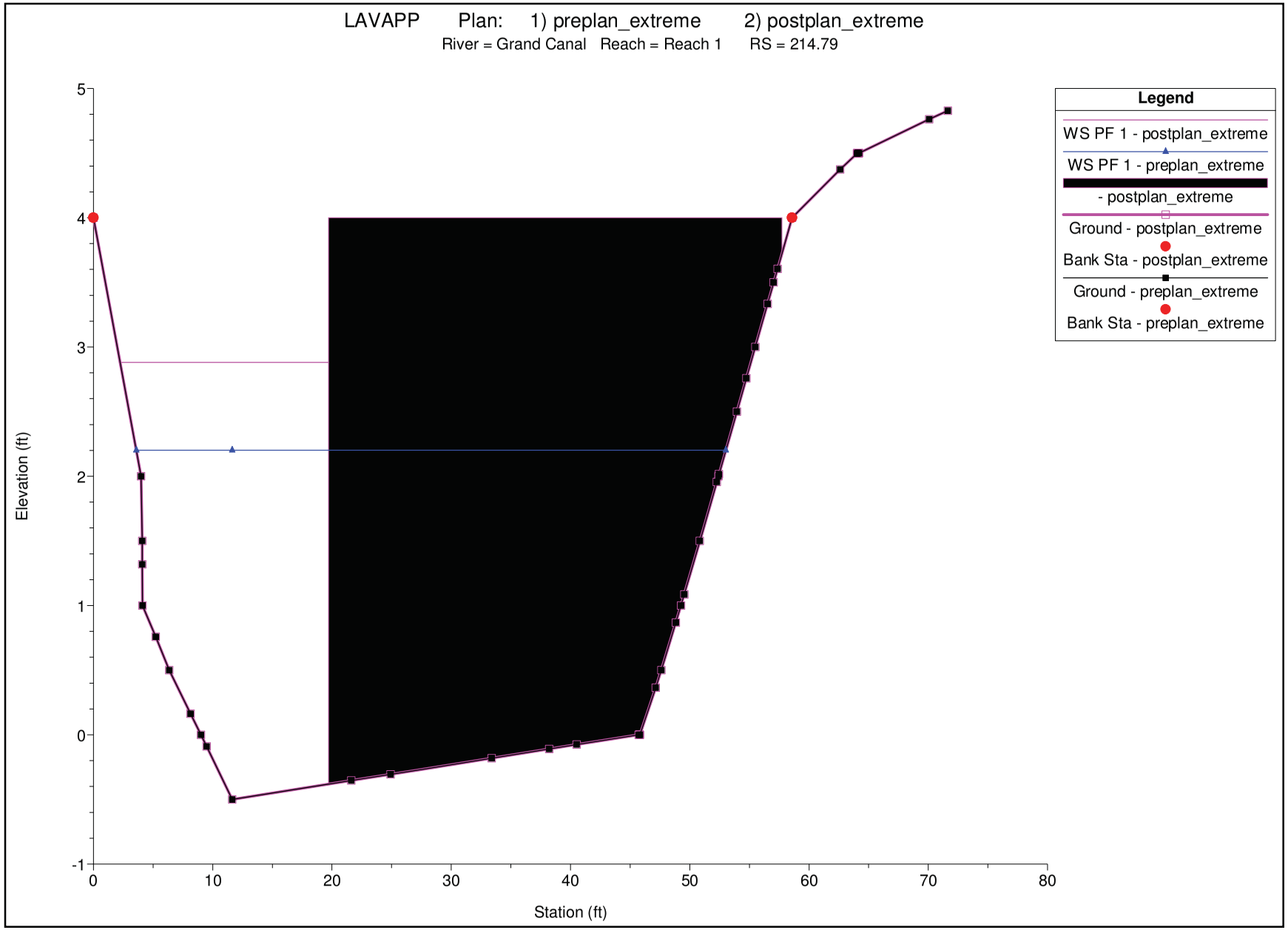
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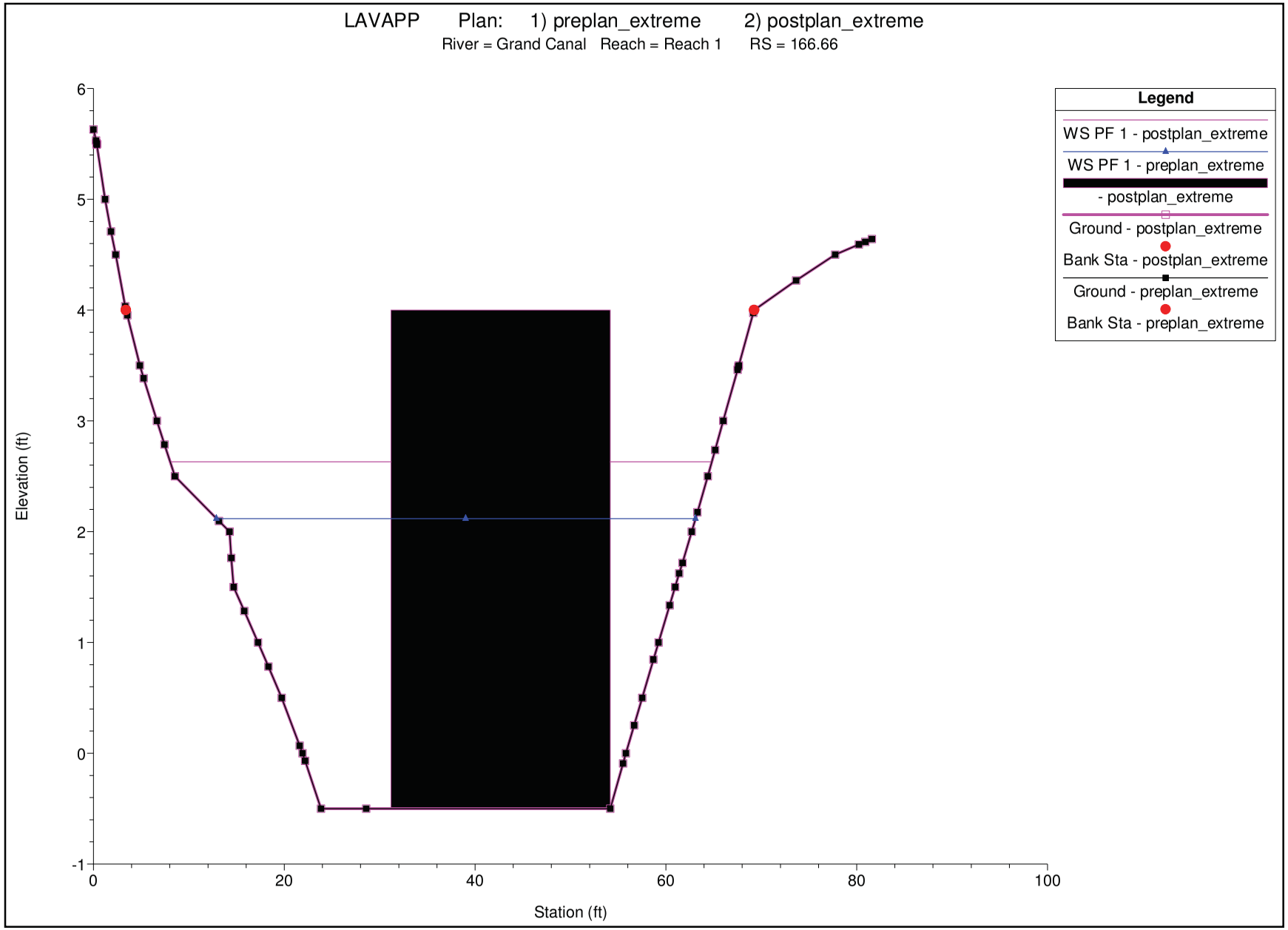
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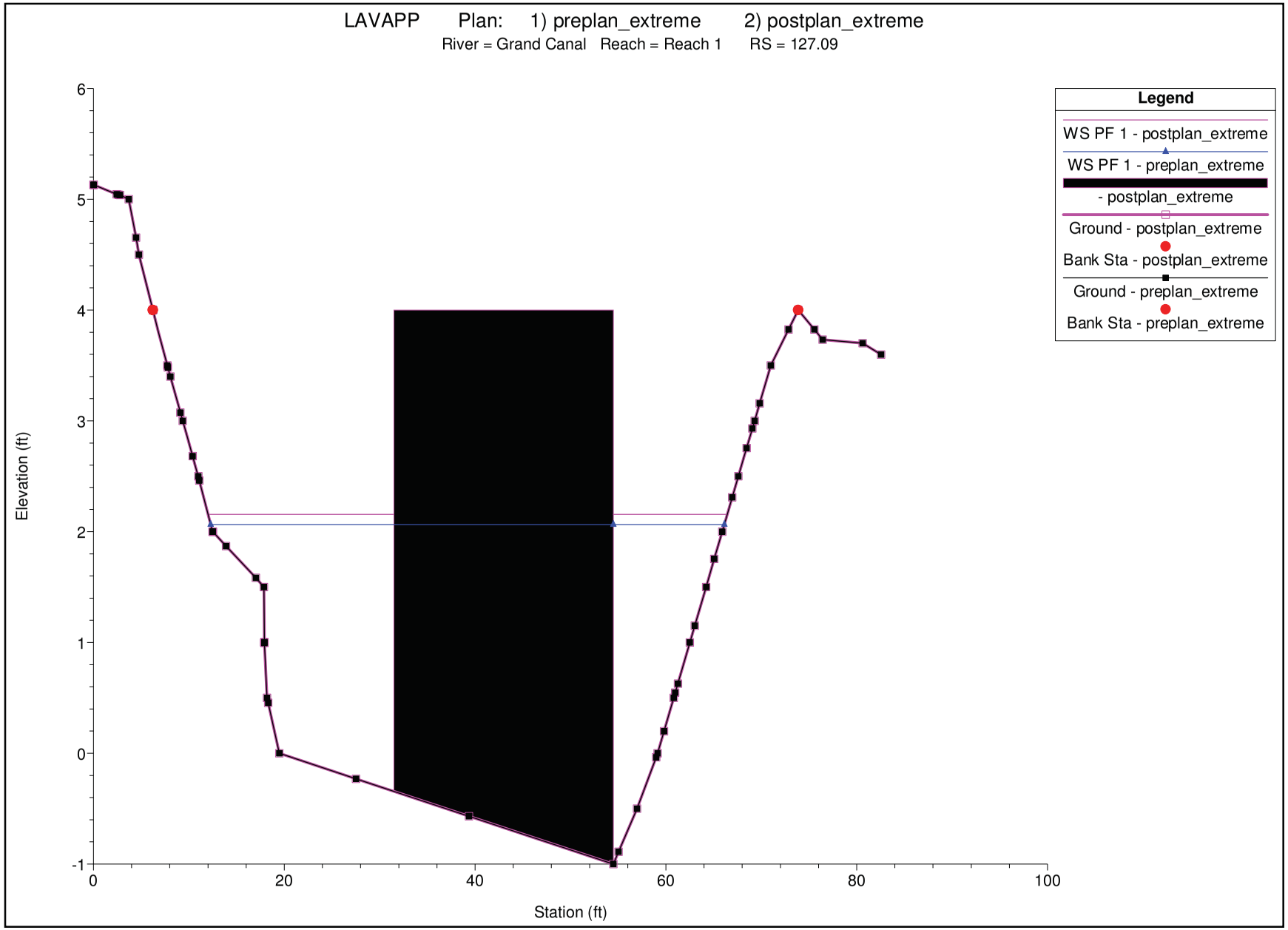
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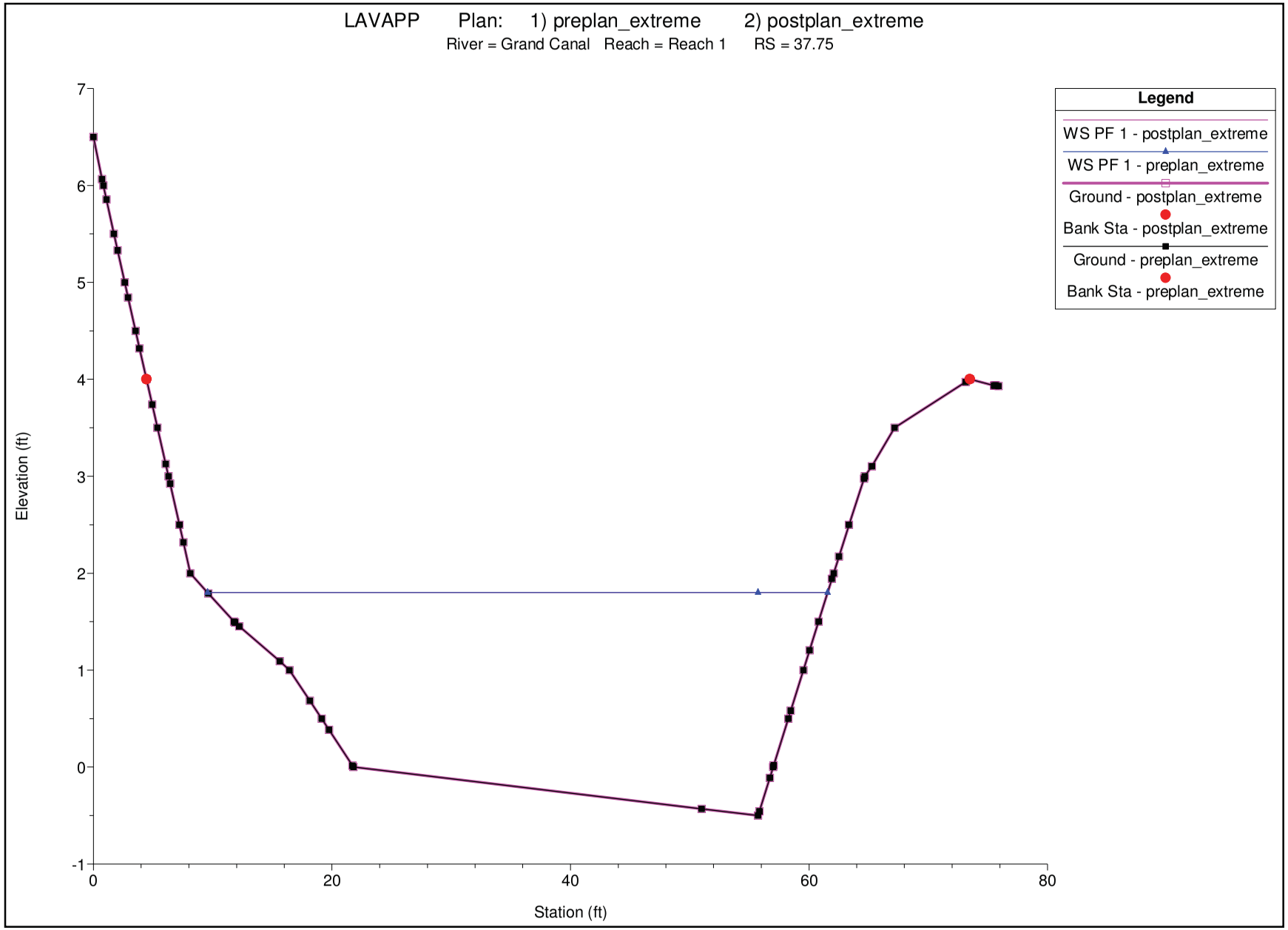
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APPENDIX K
VENICE AUXILIARY PUMPING PLANT (VAPP) WATER QUALITY SAMPLING REPORT

Venice Auxiliary Pumping Plant (VAPP)
Water Quality Sampling Report

July 8th, 2015

Prepared by

CITY OF LOS ANGELES
Department of Public Works
LA Sanitation
Environmental Monitoring Division

Prepared for

City of Los Angeles
Department of Public Works
Bureau of Engineering
Environmental Management Group

Subject: Venice Auxiliary Pumping Plant (VAPP) Water Quality Sampling

Overview

On June 5th, 2015, the Department of Public Works, Bureau of Engineering, Environmental Management Group requested baseline testing of the water quality in the Grand Canal near a construction project at the Venice Auxiliary Pumping Plant (VAPP) in Venice, California, between Hurricane Street and Galleon Street (see copy of memo at the end of this document). The canal is within a coastal intertidal wetland and covered under the *California Environmental Quality Act*. Baseline data for the following water quality parameters were requested: pH, temperature, dissolved oxygen (DO), turbidity, and total suspended solids (TSS). A visual assessment for any floating particles, including hydrocarbons, was also requested.

Materials and Methods

- Project area photographs were captured during two field reconnaissance visits; June 10 and June 26, 2015.
- The construction project was already underway prior to reconnaissance visits.
- Construction had already begun when samples were collected the morning and early afternoon of July 1st, 2015.
- YSI Sonde 6600 v2 was used to measure temperature, salinity, turbidity, and dissolved oxygen (DO). A separate handheld pH probe was used due to malfunction of the YSI pH probe.
- Salinity, DO, turbidity, and pH were all calibrated in the lab the morning of the field sampling.
- Total suspended solids (TSS) samples were collected in conjunction with YSI Sonde measurements.
- A field duplicate TSS sample was collected at the 'downstream, outgoing tide' station. Duplicate reading of TSS were made on the 'upstream, incoming tide' sample
- Sampling site (station) coordinates were captured using an iPhone.
- TSS samples were analyzed at the Environmental Monitoring Division Laboratory, Conventional Chemistry Section, Process Control Unit, in Playa del Rey, California.
- A laboratory duplicate TSS sample was analyzed with the 'upstream, incoming tide' sample.
- YSI Sonde turbidity values were verified in the lab using the samples collected for TSS.

Site photographs:

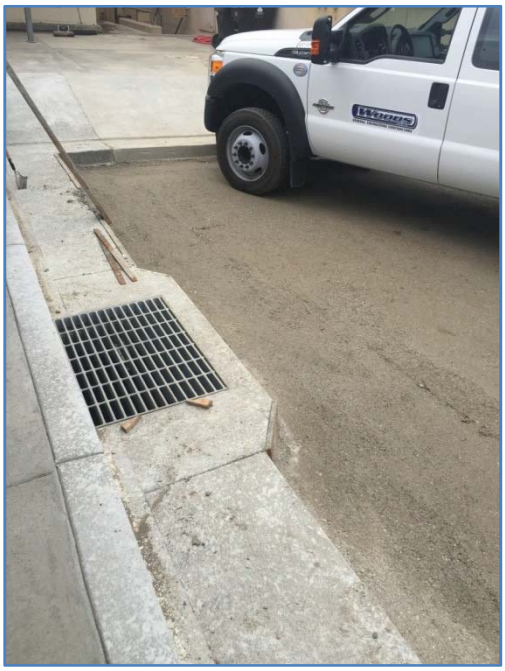
Construction site reconnaissance, June 10, 2015. Grand Canal looking southeast toward Hurricane Street with culvert indicated with arrow.

Construction site reconnaissance, June 26, 2015. Cement piles near drain that flows into canal, but no contamination was apparent

Station Locations:

Sampling Day Conditions (July 1, 2015):

- High tide: 10:21 AM (3.9 ft), Low tide 3:58 PM (-0.9 ft)
- Sampled upstream at Station 2 at 10:04 AM
- Sampled downstream at Station 3 at 1:35 PM



Cement piles near drain were absent on sampling day.

Results

Station	Date	Time	Lat	Lon	Temp (°C)	Sal (ppt)	pH	In situ Turbidity (ntu)	Discrete Turbidity (ntu)	DO (mg/)L	DO (% sat)	TSS (mg/L)
2	1-Jul-15	10:04AM	33.976263	-118.461190	23.49	33.65	8.30	1.5	6.79	6.23	88.8	40
Lab Dup												44
3	1-Jul-15	1:35PM	33.975952	-118.460886	24.93	34.17	8.38	1.4	2.82	6.91	101.3	51.2
Field Dup												43.6

Note: No anthropogenic particles or hydrocarbons were observed at any of the stations. YSI Sonde data files available upon request.
Station 2 = upstream, incoming tide
Station 3 = downstream, outgoing tide
File name: VeniceAuxPumpingPlant.xlsx

Memo request from Bureau of Engineering:

FORM GEN. 160 (Rev. 11-02)

CITY OF LOS ANGELES
INTERDEPARTMENTAL CORRESPONDENCE

Date: June 5, 2015

To: Mas Dojiri,
Wastewater Treatment Lab Manager III
Environmental Monitoring Division, MS 535
Department of Public Works, Bureau of Sanitation

From: Dr. Jan Green Rebstock
Environmental Supervisor II
Environmental Management Group, MS 939
Department of Public Works, Bureau of Engineering

Subject: VENICE AUXILARY PUMPING PLANT (VAAP) PROJECT
(W.O. SZC12923)

We are in need of baseline water quality data for the vicinity of the Grand Canal and Ballona Lagoon. The proposed project referenced above involves construction of a diversion structure within the banks of the Grand Canal, adjacent to the currently vacant lot east of the existing Venice Pumping Plant in the community of Venice, between Hurricane Street and Galleon Street. The canal is within an intertidal coastal wetland. EMG is initiating its review under the *California Environmental Quality Act* and preparing a Mitigated Negative Declaration. Anticipated required permits include Section 404 from the Army Corp of Engineers and a Section 401 water quality certification (WQC) under the *Clean Water Act*. Because water quality impacts from construction activities in the Grand Canal are likely, baseline water quality data is needed. The WQC requires water quality testing, pre and post construction.

Please provide two discrete water quality samples, one at low tide and one at high tide, using the following variables:

- pH
- temperature
- dissolved oxygen
- turbidity
- total suspended solids (TSS)
- visual assessment for floating particulates, including hydrocarbons if visible

If you have any questions or need additional information, please call me at (213) 485-5761. Thank you for your prompt attention.

CC: Curtis Cash, Bureau of Sanitation, EMD
Stan Asato, Bureau of Sanitation, EMD

APPENDIX L
CALIFORNIA COASTAL COMISSION SEA LEVEL RISE POLICY GUIDANCE

California Coastal Commission
Sea Level Rise Policy Guidance

Interpretive Guidelines for Addressing Sea Level Rise in Local Coastal Programs and Coastal Development Permits

Sunset Beach, Photo by Mario Fernandez

Chula Vista, Photo by Lisa Cox

San Francisco, Photo by Mike Baird

Arcata, Photo by Humboldt Baykeeper

Unanimously Adopted – August 12, 2015

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CALIFORNIA COASTAL COMMISSION
45 FREMONT, SUITE 2000
SAN FRANCISCO, CA 94105- 2219
VOICE (415) 904- 5200
FAX (415) 904- 5400
TDD (415) 597-5885

The ***California Coastal Commission Sea Level Rise Policy Guidance: Interpretive Guidelines for Addressing Sea Level Rise in Local Coastal Programs and Coastal Development Permits*** was **unanimously adopted** by the California Coastal Commission on August 12, 2015.

CALIFORNIA COASTAL COMMISSION

Commissioners

Steve Kinsey, *Chair* Dayna Bochco, *Vice Chair*

Gregory Cox
Carole Groom
Erik Howell
Martha McClure
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Ex Officio Members

John Laird/Janelle Beland
Lt. Gov. Gavin Newsom/Jennifer Lucchesi/Kevin Schmidt
Brian P. Kelly/Dale Jones

This report was prepared with financial assistance from the National Oceanic and Atmospheric Administration under the Coastal Zone Management Act Section 309 Enhancement Grant Program

SUMMARY OF DOCUMENT REVISIONS

A Draft version of this Guidance was released for public review on October 14, 2013. The public comment period was open for 120 days, until February 14, 2014. During that time, the Commission received over 100 comment letters that broke down into over 800 distinct comments. After the close of the public comment period, Commission staff responded to each comment and incorporated the feedback into a Revised Draft. A document containing all comments and responses is available on the Commission's website. Many alterations were made to the Draft Guidance, and the most significant include:

- *A new section on using scenario-based analysis to approach sea level rise planning*
- *A new section on storms, extreme events, abrupt change, and sea level rise*
- *A new section on sea level rise adaptation planning and environmental justice*
- *A revised chapter on sea level rise adaptation strategies, including additional strategies*
- *A new chapter on the legal context of adaptation planning*

The Revised Draft was released on May 27, 2015. This document was presented at the June 2015 Coastal Commission hearing in Newport Beach, and a presentation focusing specifically on Chapter 7 was given at the July 2015 hearing in Ventura. Written comments were requested by July 10, 2015, and 28 comment letters were submitted. Staff responded to each comment, and these responses are posted on the Coastal Commission website. The most significant revisions to the Recommended Final Draft include:

- *New text in Chapter 8, the Legal Context of Adaptation Planning, expanding the discussion of seawalls in the context of existing development versus new development, and addressing the planning considerations of highly urbanized areas*
- *New text clarifying the intent of this Guidance to focus on LCPs and CDPs, but that much of the content of the document is potentially applicable to other planning documents*
- *Additional text clarifying the unique challenges faced by low-income communities and the need to include low-income persons and communities in planning efforts*
- *Additional text recognizing the increasing demand for funding for sea level rise adaptation planning*
- *Additional Adaptation Strategies*
- *Additional Next Steps*

All revisions were coordinated with other California state efforts related to climate change and adaptation, including the 2014 *Safeguarding California* document (CNRA 2014). The Final Draft reflects the broad concepts and strategies in *Safeguarding California* — particularly the Coast and Oceans chapter — and complements it by providing information more specific to the Coastal Act, including Local Coastal Programs and Coastal Development Permits.

On August 12, 2015 the Commission adopted the Recommended Final Draft (dated July 31, 2015 and updated with addenda August 10, 2015) as interpretive guidelines pursuant to Public Resources Code section 30620.

How to Use this Document

This document is:	This document is NOT:
Guidance	**Regulations**
This Guidance is advisory and not a regulatory document or legal standard of review for the actions that the Commission or local governments may take under the Coastal Act. Such actions are subject to the applicable requirements of the Coastal Act, the federal Coastal Zone Management Act, certified Local Coastal Programs, and other applicable laws and regulations as applied in the context of the evidence in the record for that action.	
Dynamic	**Static**
This Guidance will be updated periodically to address new sea level rise science, information, and approaches regarding sea level rise adaptation, and new legal precedent. The Commission will also continue working on sea level rise through other projects and in a collaborative manner, as outlined in Chapter 9: Next Steps*.*	
Multi-purpose for multiple audiences	**Meant to be read cover-to-cover**
This Guidance is a comprehensive, multi-purpose resource and it is intended to be useful for many audiences. As such, it includes a high level of detail on many subjects. However, chapters were written as stand-alone documents to provide usable tools for readers.	
A menu of options	**A checklist**
*Since this document is intended for use statewide, it is not specific to a particular geographic location or development intensity (*e.g.*, urban or rural locations).Therefore, not all of the content will be applicable to all users, and readers should view the content as a menu of options to use only if relevant, rather than a checklist of required actions.*	

Reading Tips

- Look carefully at the Table of Contents and identify sections of interest.
- Do not expect all of the content to apply to your particular situation. As a statewide document, a wide variety of information is included to address the concerns of various users.
- Navigate to your desired level of detail: The *Executive Summary* provides a basic summary of the content; the body of the document provides a detailed discussion; and the *Appendices* provide more scientific and technical detail and a variety of useful resources.

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Commonly Used Acronyms and Agency Names

Terms:

CCT – California Coastal Trail

CDP – Coastal Development Permit

CoSMoS – Coastal Storm Modeling System

ENSO – El Niño Southern Oscillation

ESHA – Environmentally Sensitive Habitat Area

GHG – Greenhouse gas

IPCC – Intergovernmental Panel on Climate Change

LCP – Local Coastal Program

LUP – Land Use Plan

NRC Report – National Research Council Report "*Sea-Level Rise for the Coasts of California, Oregon, and Washington: Past, Present, and Future*"

PDO – Pacific Decadal Oscillation

SLR – Sea level rise

TNC – The Nature Conservancy

Agency Names:

BCDC – San Francisco Bay Conservation and Development Commission

BOEM – Bureau of Ocean Energy Management

BSEE – Bureau of Safety and Environmental Enforcement

Cal OES – California Governor's Office of Emergency Services

Caltrans – California Department of Transportation

CCC/Commission – California Coastal Commission

CDFW – California Department of Fish and Wildlife

CNRA – California Natural Resources Agency

CO-CAT – Coast and Oceans Climate Action Team

Conservancy – California State Coastal Conservancy

EPA – Environmental Protection Agency

FEMA – Federal Emergency Management Agency

NERR – National Estuarine Research Reserve

NMS – National Marine Sanctuary

NOAA – National Oceanic and Atmospheric Administration

NPS – National Park Service

OPC – California Ocean Protection Council

OPR – California Governor's Office of Planning and Research

State Lands – California State Lands Commission

State Parks – California Department of Parks and Recreation

SWRCB – State Water Resources Control Board

USACE – United States Army Corps of Engineers

USFWS – United States Fish and Wildlife Service

USGS – United States Geological Survey

Executive Summary

Climate change is upon us, affecting almost every facet of California's natural and built environment. Increasing global temperatures are causing significant effects at global, regional, and local scales. In the past century, average global temperature has increased by about 0.8°C (1.4°F), and average global sea level has increased by 7 to 8 in (17 to 21 cm) (IPCC 2013). Sea level at the San Francisco tide gauge has risen 8 in (20 cm) over the past century, and the National Research Council (NRC) projects that by Year 2100, sea level in California may rise by 4 to 56 in (10 to 143 cm) for areas north of Cape Mendocino and 17 to 66 in (42 to 167 cm) for areas south of Cape Mendocino (NRC 2012). While the California coast regularly experiences erosion, flooding, and significant storm events, sea level rise will exacerbate these natural forces, leading to significant social, environmental, and economic impacts. The third National Climate Assessment notes that there is strong evidence showing that the cost of doing nothing to prepare for the impacts of sea level rise exceeds the costs associated with adapting to them by about 4 to 10 times (Moser *et al*. 2014). Therefore, it is critically important that California plan and prepare for the impacts of sea level rise to ensure a resilient California coast for present and future generations.

The California Coastal Act is one of the state's primary coastal management laws for addressing land use, public access and recreation, and the protection of coast and ocean resources in the coastal zone. It is also the primary coastal hazards law governing development along the coast. Using the Coastal Act, the Coastal Commission and local governments have more than four decades of experience managing coastal development, including addressing the challenges presented by coastal hazards like storms, flooding, and erosion as well as responses to these hazards such as armoring. However, sea level rise and the changing climate present management challenges of a new magnitude, with the potential to significantly threaten many coastal resources, including shoreline development, coastal beach access and recreation, habitats, agricultural lands, cultural resources, and scenic resources, all of which are subject to specific protections and regulations in the Coastal Act. Therefore, effective implementation of the Coastal Act and the protection of California's coast must address global sea level rise and the greater management challenges it will bring.

This document focuses specifically on how to apply the Coastal Act to the challenges presented by sea level rise through Local Coastal Program (LCP) certifications and updates and Coastal Development Permit (CDP) decisions. It organizes current science, technical, and other information and practices into a single resource to facilitate implementation of the Coastal Act by coastal managers at the state and local level. While the document is intended to guide LCP planning and development decisions to ensure effective coastal management actions, it is advisory and does not alter or supersede existing legal requirements, such as the policies of the Coastal Act and certified LCPs. However, one of the Commission's priority goals is to coordinate with local governments to complete and update LCPs in a manner that adequately addresses sea level rise and reflects the recommendations in this Guidance.

This Guidance document is also part of a larger statewide strategy to respond to climate change that includes both emissions reductions and adaption planning to address the impacts of a changing climate. In 2008, Governor Schwarzenegger issued an Executive Order (S-13-08) directing state agencies to consider sea level rise as part of planning projects and to support the preparation of the National Research Council report on sea level rise. Additionally, on April 29,

2015, Governor Brown issued an Executive Order (B-30-15) to establish a new greenhouse gas emission reduction target and called for further action on adaptation. This Guidance is also being coordinated with many statewide initiatives to address climate change and sea level rise, including the 2014 *Safeguarding California* plan (an update to the 2009 *California Adaptation Strategy*; CNRA 2009, 2014), the ongoing update to the *General Plan Guidelines* (Cal OPR 2015), the 2013 update to the California Governor's Office of Emergency Services' (Cal OES) *State Hazard Mitigation Plan*, and others.[1] Commission staff has also been and will continue to participate in multi-agency partnerships, including the Coast and Ocean Workgroup of the multi-state agency Climate Action Team and the *State Coastal Leadership Group on Sea-Level Rise*. For more detail on these efforts, see the Introduction.

PRINCIPLES FOR ADDRESSING SEA LEVEL RISE IN THE COASTAL ZONE

This Guidance is rooted in certain fundamental guiding principles, many of which derive directly from the requirements of the Coastal Act. These Principles broadly lay out the common ideas and a framework by which sea level rise planning and permitting actions can be assessed, and as such represent the goals to which actions should aspire. Individual actions and outcomes may vary based on a variety of factors, including applicable policies and location- or project-specific factors that may affect feasibility. The Guiding Principles are summarized below and discussed in greater detail in Chapter 2.

Use Science to Guide Decisions [Coastal Act Sections 30006.5; 30335.5]

1. Acknowledge and address sea level rise as necessary in planning and permitting decisions.
2. Use the best available science to determine locally relevant and context-specific sea level rise projections for all stages of planning, project design, and permitting reviews.
3. Recognize scientific uncertainty by using scenario planning and adaptive management techniques.
4. Use a precautionary approach by planning and providing adaptive capacity for the highest amounts of possible sea level rise.
5. Design adaptation strategies according to local conditions and existing development patterns, in accordance with the Coastal Act.

Minimize Coastal Hazards through Planning and Development Standards [Coastal Act Sections 30253, 30235; 30001, 30001.5]

6. Avoid significant coastal hazard risks to new development where feasible.
7. Minimize hazard risks to new development over the life of authorized structures.
8. Minimize coastal hazard risks and resource impacts when making redevelopment decisions.

[1] See the Governor's Office of Planning and Research's webpage for the California Climate Change Document, which includes a matrix of additional efforts. Available at: http://opr.ca.gov/s_publications.php

9. Account for the social and economic needs of the people of the state; assure priority for coastal-dependent and coastal-related development over other development.
10. Ensure that property owners understand and assume the risks, and mitigate the coastal resource impacts, of new development in hazardous areas.

Maximize Protection of Public Access, Recreation, and Sensitive Coastal Resources [Coastal Act Chapter 3 policies]

11. Provide for maximum protection of coastal resources in all coastal planning and regulatory decisions.
12. Maximize natural shoreline values and processes; avoid expansion and minimize the perpetuation of shoreline armoring.
13. Recognize that sea level rise will cause the public trust boundary to move inland. Protect public trust lands and resources, including as sea level rises. New shoreline protective devices should not result in the loss of public trust lands.
14. Address other potential coastal resource impacts (wetlands, habitat, agriculture, scenic, *etc.*) from hazard management decisions, consistent with the Coastal Act.
15. Address the cumulative impacts and regional contexts of planning and permitting decisions.
16. Require mitigation of unavoidable coastal resource impacts related to permitting and shoreline management decisions.
17. Consider best available information on resource valuation when mitigating coastal resource impacts.

Maximize Agency Coordination and Public Participation [Coastal Act Chapter 5 policies; Sections 30006; 30320; 30339; 30500; 30503; 30711]

18. Coordinate planning and regulatory decision making with other appropriate local, state, and federal agencies; support research and monitoring efforts.
19. Consider conducting vulnerability assessments and adaptation planning at the regional level.
20. Provide for maximum public participation in planning and regulatory processes.

BEST AVAILABLE SCIENCE AND CONSEQUENCES OF SEA LEVEL RISE

The Coastal Act directs the Coastal Commission and local governments to use the best available science in coastal land use planning and development. This Guidance recommends using the best available science on sea level rise projections to inform planning decisions and project design. The State of California supported the preparation of the 2012 National Research Council's Report, *Sea-Level Rise for the Coasts of California, Oregon and Washington: Past, Present, and Future*, which is currently considered the best available science on sea level rise for California. The report contains sea level rise projections for three time periods over the coming century for north and south of Cape Mendocino (Table 1).[2,3] The Coastal Commission will re-examine best available science periodically and as needed with the release of new information.

In addition to these sea level rise projections, the 2012 NRC report provides information on the impacts of sea level rise in California. According to the report, sea level rise will cause flooding and inundation, increased coastal erosion, changes in sediment supply and movement, and saltwater intrusion to varying degrees along the California coast. These effects in turn could have a significant impact on the coastal economy and could put important coastal resources and coastal development at risk, including ports, marine terminals, commercial fishing infrastructure, public access, recreation, wetlands and other coastal habitats, water quality, biological productivity in coastal waters, coastal agriculture, and archaeological and paleontological resources.

Table 1. Sea Level Rise Projections for California (NRC 2012)

TIME PERIOD*	NORTH OF CAPE MENDOCINO	SOUTH OF CAPE MENDOCINO	
by 2030	-2 – 9 in (-4 – +23 cm)	2 – 12 in (4 – 30 cm)	
by 2050	-1 – 19 in (-3 – + 48 cm)	5 – 24 in (12 – 61 cm)	
by 2100	4 – 56 in (10 – 143 cm)	17 – 66 in (42 – 167 cm)	

*with Year 2000 as a baseline

[2] The NRC Committee divided the Pacific coast for California, Oregon and Washington into two regions, north and south of Cape Mendocino, due to differences in tectonics that occur at this point. North of Cape Mendocino, land is rising by 1.5 to 3.0 mm/yr as ocean plates descend below the North American plate at the Cascadia Subduction Zone. South of Cape Mendocino, the coast is sinking at an average rate of about 1 mm/yr, although local rates vary widely (NRC 2012, p. 3). Humboldt Bay has not experienced the regional uplift that characterizes most of the coast north of Cape Mendocino, and instead has shown the highest subsidence recorded for the California coast. As a result, the projections for north of Cape Mendocino may not be appropriate for use in or near Humboldt Bay and the Eel River Estuary. Please see *Humboldt Bay: Sea Level Rise Hydrodynamic Modeling, and Inundation Vulnerability Mapping* (Northern Hydrology and Engineering 2015) for additional information on sea level rise projections for the Humboldt Bay region.

[3] Any future updates to the state guidance document will be available at http://www.opc.ca.gov/2009/12/climate-change/.

ADDRESSING SEA LEVEL RISE IN LOCAL COASTAL PROGRAMS

This document provides a step-by-step process for addressing sea level rise and adaptation planning in new and updated Local Coastal Programs. These Steps, summarized below in text and in Figure 1, can be tailored to fit the needs of individual communities and to address the specific coastal resource and development issues of a community, such as dealing with bluff erosion or providing for effective redevelopment, urban infill, and concentration of development in already developed areas. Ideally, Commission and local government staff will establish regular coordination and work together in the early steps of any LCP planning process. For a detailed explanation of these LCP planning Steps, see Chapter 5. Communities in areas where sea level rise vulnerability assessment work is already underway can start later in the process, at Step 4, or other relevant Step(s).

Step 1. **Determine a range of sea level rise projections relevant to LCP planning area/segment** using best-available science, which is currently the 2012 NRC Report.

Step 2. **Identify potential physical sea level rise impacts in the LCP planning area/segment**, including inundation, storm flooding, wave impacts, erosion, and/or saltwater intrusion into freshwater resources.

Step 3. **Assess potential risks from sea level rise to coastal resources and development in the LCP planning area/segment,** including those resources addressed in Chapter 3 of the Coastal Act.

Step 4. **Identify adaptation measures and LCP policy options** to include in the new or updated LCP, including both general policies and ordinances that apply to all development exposed to sea level rise, and more targeted policies and land use changes to address specific risks in particular portions of the planning area.

Step 5. **Draft updated or new LCP for certification with California Coastal Commission**, including the Land Use Plan and Implementing Ordinances.

Step 6. **Implement the LCP and monitor and re-evaluate strategies as needed** to address new circumstances relevant to the area.

Planning Process for Local Coastal Programs and Other Plans

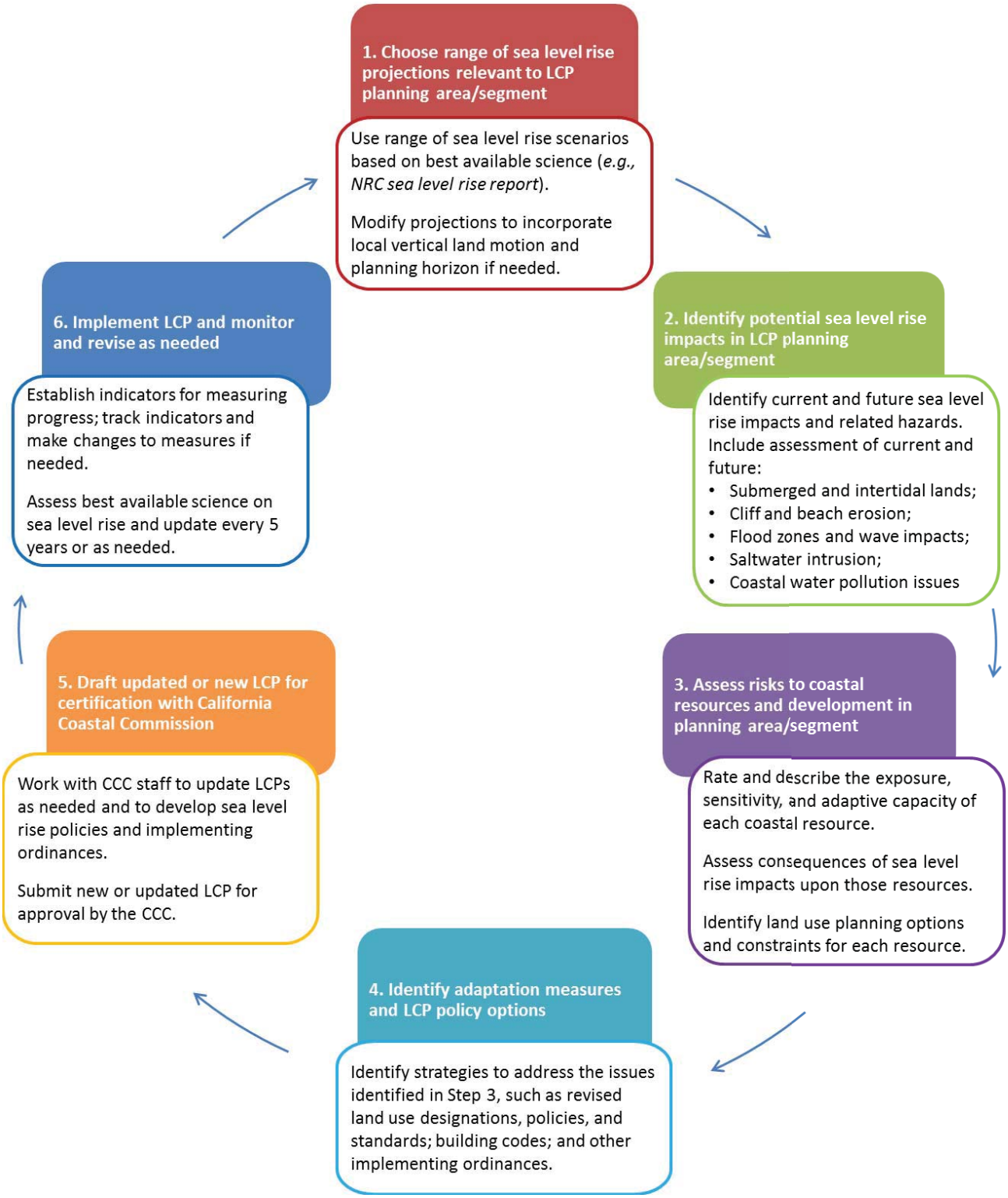
1. Choose range of sea level rise projections relevant to LCP planning area/segment
Use range of sea level rise scenarios based on best available science (*e.g., NRC sea level rise report*).
Modify projections to incorporate local vertical land motion and planning horizon if needed.
2. Identify potential sea level rise impacts in LCP planning area/segment
Identify current and future sea level rise impacts and related hazards. Include assessment of current and future:
• Submerged and intertidal lands;
• Cliff and beach erosion;
• Flood zones and wave impacts;
• Saltwater intrusion;
• Coastal water pollution issues
3. Assess risks to coastal resources and development in planning area/segment
Rate and describe the exposure, sensitivity, and adaptive capacity of each coastal resource.
Assess consequences of sea level rise impacts upon those resources.
Identify land use planning options and constraints for each resource.
4. Identify adaptation measures and LCP policy options
Identify strategies to address the issues identified in Step 3, such as revised land use designations, policies, and standards; building codes; and other implementing ordinances.
5. Draft updated or new LCP for certification with California Coastal Commission
Work with CCC staff to update LCPs as needed and to develop sea level rise policies and implementing ordinances.
Submit new or updated LCP for approval by the CCC.
6. Implement LCP and monitor and revise as needed
Establish indicators for measuring progress; track indicators and make changes to measures if needed.
Assess best available science on sea level rise and update every 5 years or as needed.

Figure 1. Flowchart for addressing sea level rise in Local Coastal Programs and other plans

ADDRESSING SEA LEVEL RISE IN COASTAL DEVELOPMENT PERMITS

New development within the coastal zone generally requires a Coastal Development Permit (CDP). Many projects reviewed through the CDP application process already examine sea level rise impacts as part of the hazards analysis, though not every CDP application will need to consider sea level rise. In general, sea level rise is only likely to affect those projects that are on low-lying land, on eroding coastal bluffs, are in close proximity to water, or rely upon a shallow aquifer for water supply. This document offers a step-by-step outline, summarized below in text and in Figure 2, for how to conduct such an analysis as a standard part of the CDP application process. The goal of these Steps is to ensure careful attention to minimizing risk to development and avoiding impacts to coastal resources over the life of the project. Early coordination with the Coastal Commission staff is highly recommended, and staff will be available to consult with applicants during this process. Adopting or updating LCPs as recommended in this Guidance should facilitate subsequent review of CDPs. LCPs can identify areas where a closer review of sea level rise concerns is necessary. If kept up to date, they can also provide information for evaluation at the permit stage and specify appropriate mitigation measures for CDPs to incorporate. For a detailed explanation of these steps, see Chapter 6 of this Guidance.

Step 1. **Establish the projected sea level rise range for the proposed project**'s planning horizon using the best available science, which is currently the 2012 NRC Report.

Step 2. **Determine how physical impacts from sea level rise may constrain the project site,** including erosion, structural and geologic stability, flooding, and inundation.

Step 3. **Determine how the project may impact coastal resources, considering the influence of future sea level rise upon the landscape** as well as potential impacts of sea level rise adaptation strategies that may be used over the lifetime of the project.

Step 4. **Identify alternatives to avoid resource impacts and minimize risks** throughout the expected life of the development.

Step 5. **Finalize project design and submit CDP application.**

Planning Process for Coastal Development Permits

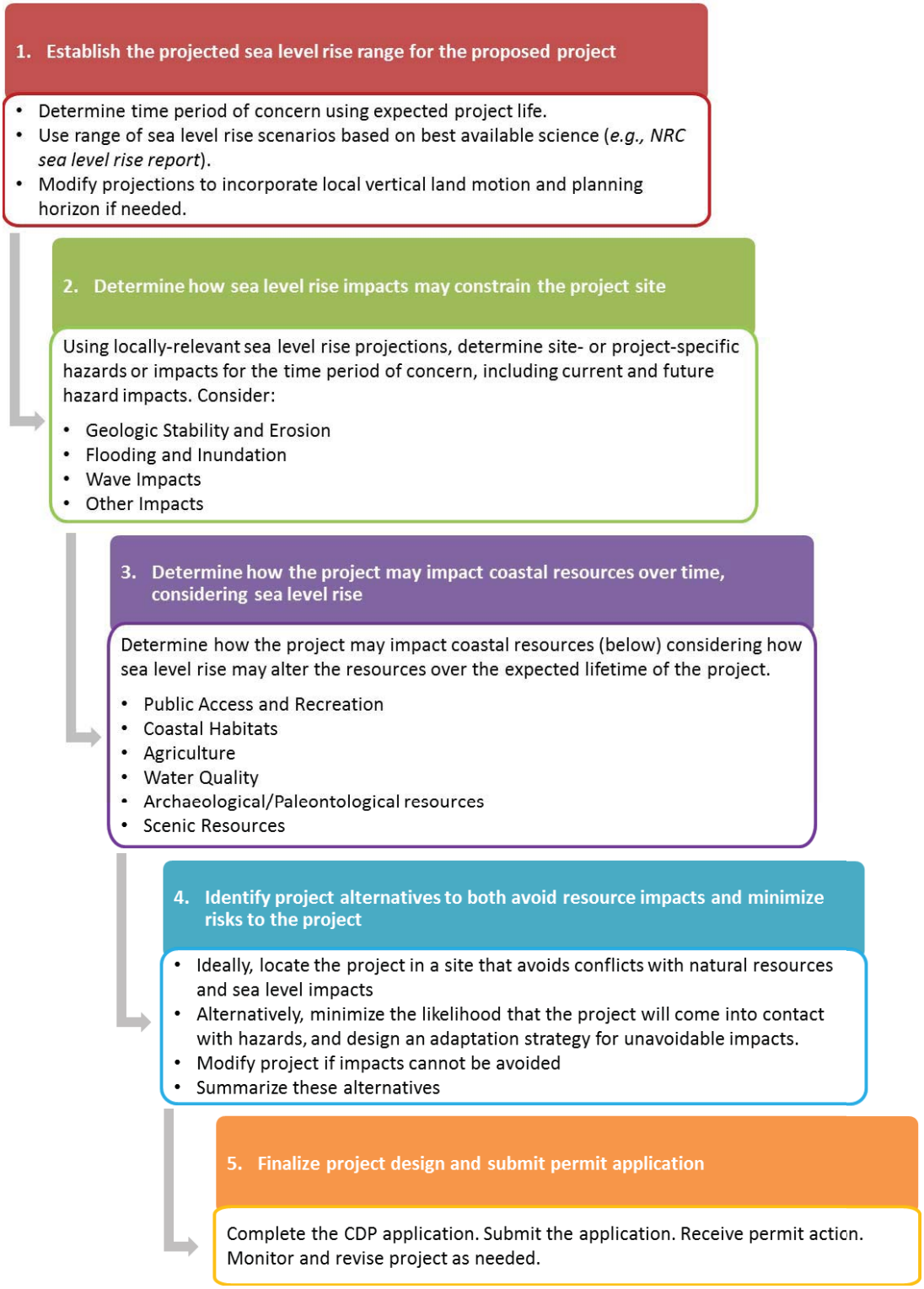
1. Establish the projected sea level rise range for the proposed project
• Determine time period of concern using expected project life.
• Use range of sea level rise scenarios based on best available science (e.g., NRC sea level rise report).
• Modify projections to incorporate local vertical land motion and planning horizon if needed.
2. Determine how sea level rise impacts may constrain the project site
Using locally-relevant sea level rise projections, determine site- or project-specific hazards or impacts for the time period of concern, including current and future hazard impacts. Consider:
• Geologic Stability and Erosion
• Flooding and Inundation
• Wave Impacts
• Other Impacts
3. Determine how the project may impact coastal resources over time, considering sea level rise
Determine how the project may impact coastal resources (below) considering how sea level rise may alter the resources over the expected lifetime of the project.
• Public Access and Recreation
• Coastal Habitats
• Agriculture
• Water Quality
• Archaeological/Paleontological resources
• Scenic Resources
4. Identify project alternatives to both avoid resource impacts and minimize risks to the project
• Ideally, locate the project in a site that avoids conflicts with natural resources and sea level impacts
• Alternatively, minimize the likelihood that the project will come into contact with hazards, and design an adaptation strategy for unavoidable impacts.
• Modify project if impacts cannot be avoided
• Summarize these alternatives
5. Finalize project design and submit permit application
Complete the CDP application. Submit the application. Receive permit action. Monitor and revise project as needed.

Figure 2. Flowchart for addressing sea level rise in Coastal Development Permits

ADAPTATION STRATEGIES

Steps 1 through 3 of the processes for addressing sea level rise in LCPs and CDPs will help planners and project applicants identify particular vulnerabilities to the planning region and specific project sites. Such vulnerabilities may include impacts to a number of resources identified in the Coastal Act, including development and infrastructure; public access and recreational opportunities; beaches, wetlands, environmentally sensitive habitat areas (ESHA), and other coastal habitats; agricultural resources; water quality; archaeological and paleontological resources; and scenic and visual resources. Planners and project applicants will need to identify, develop, and implement various adaptation strategies designed to protect coastal resources. These strategies should fulfill the hazard minimization and resource impact avoidance policies of the Coastal Act and should account for local conditions. In many cases, strategies will need to be implemented incrementally as conditions change, and planners, project applicants, and partners will need to think creatively and adaptively to ensure that coastal resources and development are protected over time. Chapter 7 of this Guidance summarizes a number of strategies to protect different coastal resources and meet the goals and requirements of the Coastal Act.

ADDITIONAL INFORMATION

In addition to providing a summary of best available science on sea level rise, step-by-step approaches for addressing sea level rise in LCPs and CDPs, and a discussion of numerous adaptation strategies, the Guidance includes the following supplemental information:

- A brief discussion of the legal context of adaptation
- Next steps for Commission staff in coordination with other relevant partners and research institutions, based on objectives and actions from the Commission adopted *California Coastal Commission Strategic Plan 2013-2018* (2013a)
- Additional research needs directed toward research institutions at academic, state, federal, and local levels to help communities understand and prepare for sea level rise
- Detailed information on the drivers of sea level rise and sea level rise projections
- A step-by-step methodology for assessing local hazard conditions based on regional sea level rise projections, which is applicable to both LCPs and CDPs
- Lists of useful resources and references, including examples of sea level rise adaptation documents from other state agencies
- Key Coastal Act policies relevant to sea level rise and coastal hazards

CONTEXT OF THIS DOCUMENT

This Guidance is part of a larger body of work on climate change by State agencies, regional collaborations, local leadership, academic research, and other organizations. Many of these efforts are included as resources in Appendix C. Users of the document should take advantage of these existing resources, collaborate with others, and share best practices as much as possible.

Finally, this document is intended to function as interpretive guidance for effective implementation of the Coastal Act and LCPs in light of sea level rise. It is not a regulatory document and does not contain any new regulations. Further, it does not amend or supersede existing legal authorities or the standard of review for Local Coastal Programs and coastal development permit decisions pursuant to the Coastal Act. Those actions are subject to the applicable requirements of the Coastal Act, the Coastal Zone Management Act, certified LCPs, and other applicable laws and regulations as applied in the context of the evidence in the records for those actions. The Commission is adopting this Guidance as interpretive guidelines pursuant to its authority under Public Resources Code Sections 30620.

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Chapter 1

Introduction

Climate change is happening now. Rapidly melting ice caps, rising sea levels, floods, extreme heat waves, droughts, and fires are just a few of the effects of climate change. These effects are having profound impacts on our coast and are changing coastal management planning and decision making at global, national, state, regional, local, and individual scales.

Given current trends in greenhouse gas emissions, sea levels are expected to rise at an accelerating rate in the future, and scientists project an increase in California's sea level in coming decades. Until mid-century, the most damaging events for the California coast will likely be dominated by large El Niño-driven storm events in combination with high tides and large waves. Eventually, sea level will rise enough that even small storms will cause significant damage, and large events will have unprecedented consequences (Caldwell *et al*. 2013).

This Guidance provides a framework for addressing sea level rise in Local Coastal Programs (LCPs) and Coastal Development Permits (CDPs). The intended audience for this document includes the Commission and Commission staff, local governments, other public agencies, permit applicants, members of the public, and others who are interested in how to implement and comply with the California Coastal Act (Coastal Act) while taking steps to address sea level rise.

ENVIRONMENTAL, ECONOMIC, AND SOCIAL IMPACTS OF SEA LEVEL RISE

The potential environmental, economic, and social impacts of sea level rise in California underscore the importance of addressing the issue in land use planning and regulatory work. Just over 21 million people lived in California's coastal counties as of July 2014 (CDF 2014), and the state supports a $40 billion coastal and ocean economy (NOEP 2010).

Many aspects of the coastal economy, as well as California's broader economy, are at risk from sea level rise, including coastal-related tourism, beach and ocean recreational activities, transfer of goods and services through ports and transportation networks, coastal agriculture, and commercial fishing and aquaculture facilities.

In addition to potential losses in revenue, Heberger *et al.* (2009) estimate that $100 billion worth of property is at risk of flooding during a 100-year coastal flood with 4.6 ft (1.4 m) of sea level rise (the amount projected to occur by the year 2100 in their Pacific Institute study). This property includes seven wastewater treatment plants, commercial fishery facilities, marine terminals, Coastal Highway One, 14 power plants, residential homes, and other important development and infrastructure.

Sea level rise also poses environmental and social justice challenges. This is particularly true for communities that may be dependent upon at-risk industries, are already suffering from economic hardship, or which have limited capacity to adapt, including lower-income, linguistically isolated, elderly, and other vulnerable populations.

Proactive steps are needed to prepare for sea level rise and to protect the coastal economy, California livelihoods, and coastal resources and the ecosystem services they provide. The

magnitude of the challenge is clear – not only might the impacts of sea level rise be severe, the costs and time associated with planning for them can be daunting. The third National Climate Assessment, released in May 2014, notes that there is strong evidence to suggest that the costs of inaction are 4 to 10 times greater than the costs associated with proactive adaptation and hazard mitigation (Moser *et al*. 2014). It is critical for California to take proactive steps to address the impacts sea level rise may have on the state's economy, natural systems, built environment, human health, and ultimately, its way of life.

SEA LEVEL RISE AND THE CALIFORNIA COASTAL ACT

The potential impacts of sea level rise fall directly within the Coastal Commission's (and coastal zone local governments') planning and regulatory responsibilities under the Coastal Act. Sea level rise increases the risk of flooding, coastal erosion, and saltwater intrusion into freshwater supplies, which have the potential to threaten many of the resources[4] that are integral to the California coast, including coastal development, coastal access and recreation, habitats (*e.g.*, wetlands, coastal bluffs, dunes, and beaches), coastal agricultural lands, water quality and supply, cultural resources, community character, and scenic quality. In addition, many possible responses to sea level rise, such as construction of barriers or armoring, can have adverse impacts on coastal resources. For example, beaches, wetlands, and other habitat backed by fixed or permanent development will not be able to migrate inland as sea level rises, and will become permanently inundated over time, which in turn presents serious concerns for future public access and habitat protection.

The Coastal Act mandates the protection of public access and recreation along the coast, coastal habitats, and other sensitive resources, as well as providing priority visitor-serving and coastal-dependent or coastal-related development while simultaneously minimizing risks from coastal hazards. This Guidance document has been created to help planners, project applicants, and other interested parties continue to achieve these goals in the face of sea level rise by addressing its effects in Local Coastal Programs and Coastal Development Permits. Although the focus of the Guidance is on LCPs and CDPS, much of the information contained herein can be useful for other planning documents such as Port Master Plans[5], Long Range Development Plans, and Public Works Plans. For example, the science applies regardless of the planning documents, and the discussions of how to analyze sea level rise impacts as well as a number of adaptation options may be applicable. In all cases, specific analyses performed and actions implemented will vary based on relevant policies, local conditions, feasibility, and other factors as described throughout the rest of this document.

[4] The term "coastal resources" is used throughout this Guidance and is meant to be a general term for those resources addressed in Chapter 3 of the California Coastal Act including but not limited to beaches, wetlands, agricultural lands, and other coastal habitats; coastal development; public access and recreation opportunities; cultural, archaeological, and paleontological resources; and scenic and visual qualities.

[5] Ports are generally subject to Chapter 8 of the Coastal Act. The policies of Chapter 8 acknowledge the special role and needs of ports and differ in significant ways from the Chapter 3 policies of the Act. Significant categories of development in ports, however, remain subject to Chapter 3, including categories of development listed as appealable pursuant to Section 30715 and development located within specified wetlands, estuaries, and recreation areas.

Coastal Commission reports and briefings on sea level rise: Sea level rise is not a new concern for the Commission. The Coastal Act policies on hazard avoidance and coastal resource protection provide the basis for the Commission to consider the impacts of sea level rise (see *Appendix F: Coastal Act Policies Relevant to Sea Level Rise and Coastal Hazards*), and the Commission has long considered sea level rise, erosion rates, and other effects of a dynamic climate in its analysis of permits and LCPs, staff recommendations, and Commission decisions. In 1992, Section 30006.5 was added to the Coastal Act which, among other things, directs the Commission to both develop its own expertise and interact with the scientific community on various technical issues, including coastal erosion and sea level rise. The Commission's staff also coordinates its work on sea level rise with other state and federal agencies, local governments, academic institutions, non-profit organizations, citizen groups, permit applicants, property owners, and others.

The Commission has documented its sea level rise adaptation and climate change efforts in numerous papers and briefings, including:

- 1989 Report: *Planning for Accelerated Sea Level Rise along the California Coast*
- 2001 Report: *Overview of Sea Level Rise and Some Implications for Coastal California*
- 2006 Briefing: *Discussion Draft: Global Warming and the California Coastal Commission*
- 2008 Briefing: *A Summary of the Coastal Commission's Involvement in Climate Change and Global Warming Issues for a Briefing to the Coastal Commission*
- 2008 White paper: *Climate Change and Research Considerations*
- 2010 Briefing: *A Summary of the Coastal Commission's Involvement in Sea Level Rise Issues for a Briefing to the Coastal Commission*[6]

THE IMPORTANCE OF ADDRESSING SEA LEVEL RISE IN LOCAL COASTAL PROGRAMS

The impacts of sea level rise will be felt at the local level, and therefore local responses will necessarily be part of effective management of these impacts. Fortunately, the California Coastal Act lays out a legal and planning framework for community climate preparedness and resiliency planning. LCPs, in combination with Coastal Development Permits (CDPs), provide the implementing mechanisms for addressing many aspects of climate change within coastal communities at the local level.

The goal of updating or developing a new LCP to prepare for sea level rise is to ensure that adaptation occurs in a way that protects both coastal resources and public safety and allows for sustainable economic growth. This process includes identifying how and where to apply different adaptation mechanisms based on Coastal Act requirements, other relevant laws and policies, acceptable levels of risk, and community priorities. LCP and Coastal Act policies are also reflected in CDPs, which implement sea level rise management measures and adaptation

[6] Verbal presentation to the Coastal Commission on December 17, 2010 by Susan Hansch (Item 4.5). This presentation can be viewed at the Cal-Span website (<http://www.cal-span.org/media.php?folder[]=CCC>) from approximately minute 22.00 to 24:30.

strategies through individual development decisions. By planning ahead, communities can reduce the risk of costly damage from coastal hazards, can ensure the coastal economy continues to thrive, and can protect coastal habitats, public access and recreation, and other coastal resources for current and future generations.

The Coastal Commission has made it a priority to support the update of LCPs to address climate change, as demonstrated by Goal 3 of the Commission's *Strategic Plan* (CCC 2013a), which is to "address climate change through LCP planning, coastal permitting, inter-agency collaboration, and public education." Specifically, Objective 3.1.1 directs the Commission to "adopt general sea level rise (SLR) policy guidance for use in coastal permitting and LCP planning and amendment based on best available science, including the final report from the National Research Council (NRC) of the National Academy of Science entitled, *Sea-Level Rise for the Coasts of California, Oregon, and Washington: Past, Present, and Future* (released June 2012)." This Guidance document fulfills Objective 3.1.1 and is one of multiple ongoing Commission efforts to support local governments in updating LCPs to address sea level rise.

Funding for LCP updates: Both the *California Climate Adaptation Strategy* (CNRA 2009) and the *Safeguarding California* plan (CNRA 2014) identified amendments to LCPs as a key strategy for addressing sea level rise in California. However, there are significant funding constraints at both the Commission and local government levels that limit the capacity to update LCPs. Fortunately, three grant programs have recently been funded to support California local governments in updating LCPs to address sea level rise. These grant programs have partially overlapping objectives, as described below. Grant-related information as of the publication of this Guidance is summarized below. For up-to-date information regarding grants, please visit the Local Assistance Grant Program page on the Coastal Commission website.

- **Coastal Commission LCP Local Assistance Grant Program:** For fiscal years 2013/2014 and 2014/2015, the Coastal Commission received $1 million per year ($2 million total) in grant funds through a budget augmentation approved by Governor Brown and the California Legislature. The grant program provides funding to local governments to complete the certification of new and updated LCPs, with an emphasis on addressing impacts from sea level rise and climate change. In January 2014, the Coastal Commission awarded $1 million in LCP Grant funds to 11 jurisdictions throughout the state, with awards ranging from $29,000 to $130,000. In November 2014, the Coastal Commission awarded $1 million to 12 jurisdictions, with awards ranging from $13,000 to $250,000. This second round of funding was coordinated through a joint application and review process with the OPC LCP Sea Level Rise Grant program (below) in order to maximize funding opportunities.

- **Ocean Protection Council LCP Sea Level Rise Grant Program:** The OPC grant program includes $2.5 million to support local governments in updating LCPs to address sea level rise, including support of sea level rise modeling, vulnerability assessments, and adaptation planning and policy development. The OPC is administering the program in partnership with the Coastal Commission and the Coastal Conservancy. In November 2013, the OPC awarded $1,305,000 to seven jurisdictions based on recommendations from the three coordinating agencies. The remaining funds were awarded in the second

round of the grant program in December 2014. Seven jurisdictions received funding ranging from $90,000 to $200,000. This second round of funding was coordinated through a joint application and review process with the Coastal Commission Grant Program, as described above.

- **State Coastal Conservancy Climate Ready Grant Program:** The Climate Ready Grant Program provides funding for climate change-related projects including projects to update LCPs to address sea level rise. The Conservancy awarded $3 million in January 2014, and awarded an additional $2.4 million for a second round of grants in January 2015. The second round focuses on implementation of coastal climate change adaptation projects. A third round of grant applications is currently being reviewed. These grant funds are available to both local governments and non-governmental organizations.

Coastal Commission Staffing Increase to Support LCP planning: Governor Brown and the California Legislature also approved an augmentation to the Coastal Commission's FY 2013/2014 budget of $4 million ($3 million for state operations and $1 million for grants to local governments) for local governments and the Coastal Commission to prepare, update, amend, and review LCPs with an emphasis on including climate change issues.

The Governor's Budget for FY 2015/2016 implements the Spring Finance Letter issued April 1, 2014 that was approved as part of the FY 2014/2015 Enacted Budget. The Spring Finance Letter (April 1, 2014), added two additional years (FY 14/15 and FY 15/16) of state operations funding of $3 million for 25 limited term positions and operating expenses to the Coastal Commission's enacted budget for FY 14/15. For FY 14/15, the approved LCP staff funding is coming from $1 million in carryover General Fund and $2 million from the Coastal Act Services Fund (CASF 3123). For FY 15/16 the Governor's Budget proposes the LCP staff funding to come from $1 million in Environmental License Plate Funds (ELPF) and $2 million from the Coastal Act Services Fund.

The Coastal Act Services Fund holds the filing and permit fees that the Coastal Commission receives from applicants for regulatory actions (*e.g.*, development application fees). Because of the current reserve in the Coastal Act Services Fund, there are adequate resources to fund appropriation of $2 million for FY 14/15 and FY 15/16.

To extend the augmented LCP staff funding after FY 15/16, the Commission will need to submit a Budget Change Proposal in September 2015 for requested funding for FY 16/17 and thereafter.

COASTAL RESILIENCY AND PREPARING FOR SEA LEVEL RISE: THE FEDERAL AND STATE CONTEXT

Sea level rise planning efforts are currently taking place at the local, regional, state, and national levels. Framing the efforts in California is a federal strategy to address climate change by both reducing greenhouse gas emissions and adapting to climate change impacts. Recent efforts promoted by the White House include President Obama's January 2015 Executive Order 13960, which modifies Executive Order 11988, Floodplain Management, by expanding the federal approach for establishing flood risk to include the consideration of climate change. Specifically, it recommends using a new flood standard that accounts for climate change in establishing flood

elevation and hazard areas when federal funds are used to build, significantly retrofit, or repair structures.

Additionally, Governor Brown, Supervisor Carbajal (Santa Barbara County), Mayor Garcetti (Los Angeles), and Mayor Johnson (Sacramento) are on the President's State, Local, and Tribal Leaders Task Force on Climate Preparedness and Resilience, which recently released recommendations for how to modernize programs and policies to incorporate climate change.[7] The Coastal Commission's Guidance document implements many of the Task Force's recommendations by providing tools and assistance to support sea level rise decision making, by establishing a framework for state, local, and federal partnership and coordination on sea level rise, and by providing guidance on how to improve the resilience of California's coastal infrastructure, natural resources, human communities, and coastal industries.

The State of California has long been a leader in preparing for sea level rise, and in 2008, Governor Schwarzenegger issued an Executive Order (S-13-08) directing state agencies to prepare guidance on sea level rise and to address sea level rise in any state projects located in vulnerable areas. Since then, state agencies have worked collaboratively to accomplish a variety of different actions related to sea level rise adaptation, many of which are listed below. Ten state and federal agencies[8] also commissioned the National Research Council's report, *Sea-Level Rise for the Coasts of California, Oregon, and Washington: Past, Present, and Future* (2012), to improve understanding of sea level rise projections for California.

More recently, Governor Brown's April 2015 Executive Order B-30-15 addresses climate change and sea level rise adaptation, stating that state agencies shall take climate change into account in their planning and investment decisions. The order requires agencies to ensure that priority is given to actions that build climate preparedness and reduce greenhouse gas emissions, provide flexible and adaptive approaches, protect the state's most vulnerable populations, and promote natural infrastructure solutions. Additionally, AB2516, authored by Assemblymember Gordon and approved in September 2014, established a Planning for Sea Level Rise Database that is anticipated to be available online in early 2016. The database will provide the public with an educational tool from which to learn about the actions taken by cities, counties, regions, and various public and private entities to address sea level rise.

Much of the state's climate change adaptation work has been coordinated with the *Coast and Ocean Workgroup* of the *Climate Action Team* (CO-CAT), of which the Commission is a member. In addition, Commission staff has been involved in the *State Coastal Leadership Group on Sea-Level Rise*, which was established in early 2014 to develop and implement coordinated approaches to address sea level rise across state agencies. The partnership includes senior management from the Coastal Zone Management Agencies (Coastal Commission, San Francisco Bay Conservation and Development Commission, and State Coastal Conservancy) and land

[7] http://www.whitehouse.gov/administration/eop/ceq/initiatives/resilience/taskforce

[8] The assessment of sea level rise was commissioned by California Department of Water Resources, California Energy Commission, California Department of Transportation, California State Water Resources Control Board, California Ocean Protection Council, Oregon Watershed Enhancement Board, Washington Department of Ecology, National Oceanic and Atmospheric Administration (NOAA), US Army Corps of Engineers (USACE), and US Geological Survey (USGS).

management agencies (State Lands Commission and State Parks) along with the Ocean Protection Council and Natural Resources Agency. This Guidance is being coordinated closely with this work[9] to ensure that various initiatives do not conflict and to assure an effective response to challenges such as sea level rise.

To that end, the content of this Guidance is aligned with several key concepts in the *Safeguarding California* plan, including hazard avoidance for new development, encouraging innovative designs and adaptation strategies for structures in areas vulnerable to sea level rise hazards, and addressing climate impacts in Local Coastal Programs and General Plan updates, among many others. *Safeguarding California* also calls out the need for state agencies to produce guidance documents addressing climate adaptation, and this sea level rise Guidance is part of the statewide effort to fulfill that mandate. As *Safeguarding California* promotes, this Guidance will be a living document that will be updated and revised as sea level rise science advances and new insights are gained regarding adaptation.

State agency policies and guidance on climate change and sea level rise: As a result of the Executive Order S-13-08 and agency needs for guidance, many state agencies have developed climate change and sea level rise policies and guidance documents. For example:

- The California Natural Resources Agency (CNRA) developed the 2009 *California Climate Adaptation Strategy* and the 2014 update, *Safeguarding California*
- CNRA and the Governor's Office of Emergency Services (Cal OES) collaboratively developed the *California Climate Adaptation Planning Guide* (2012)
- The Governor's Office of Planning and Research is updating its *General Plan Guidelines* to address climate change (a draft update is anticipated in 2015)
- The Ocean Protection Council established *State Sea-Level Rise Guidance* (interim, 2010, and update, 2013) and passed a *State Sea-Level Rise Resolution* (March 11, 2011)
- The San Francisco Bay Conservation and Development Commission (BCDC) amended the *San Francisco Bay Plan* (1968) to update its policies regarding sea level rise (2011) and has been working on actions to reduce vulnerability to sea level rise throughout the San Francisco Bay through the Adapting to Rising Tides (ART) project
- The California State Coastal Conservancy (Conservancy) established climate change policies, application guidelines for sea level rise, and climate ready principles (2011)
- Cal OES updated the State Multi-Hazard Mitigation Plan in 2013
- The California Department of Transportation (Caltrans) developed guidance on incorporating sea level rise into the planning and development of Project Initiation Documents (2011), and how to address adaptation in Regional Transportation Plans (2013), and has completed numerous other climate change related activities

Other agencies including the California Department of Parks and Recreation and the California State Lands Commission are in the process of developing guidance. The California Department

[9] See the Governor's Office of Planning and Research's webpage for the California Climate Change Document which includes a matrix of additional efforts. Available at: http://opr.ca.gov/s_publications.php

of Fish and Wildlife, the Division of Boating and Waterways, and the Department of Water Resources are all actively addressing sea level rise and have taken steps to conduct research on sea level rise impacts, integrate sea level rise into planning documents, and educate staff on climate change impacts (see Appendix C for a description of these efforts).

Other efforts: Sea level rise planning efforts taking place at all levels of government and across numerous sectors helped inform this Guidance. Commission staff reviewed scientific publications on sea level rise and climate change, adaptation guidebooks, and existing adaptation principles and best practices described in documents such as *Indicators of Climate Change in California* (Cal EPA 2013), *Adapting to Sea Level Rise: A Guide for California's Coastal Communities* (Russell and Griggs 2012), *Climate Smart Conservation: Putting Adaptation Principles into Practice* (Stein *et al.* 2014), *Ecosystem Adaptation to Climate Change in California: Nine Guiding Principles* (RLF 2012), and *Climate Smart Principles* (PRBO 2013), and applied relevant information to the Guidance where applicable and consistent with the Coastal Act.

LOOKING AHEAD: PLANNING AND PROJECT DESIGN WITH SEA LEVEL RISE

The coast has always been a place of change due to land modifications such as erosion and vertical land motion, and to water variability such as tides, waves, and storms. Despite this dynamic nature, many areas of the California coast have been developed with an expectation that there will be some permanence to the land area and site safety. Development efforts have used such techniques as setbacks, avoidance of existing floodplain areas, elevation above some base flood level, and compliance with design standards to reduce or minimize coastal risks and to ensure an acceptable level of safety.

However, hazards are rarely eliminated or avoided completely. Sea level rise will exacerbate existing hazards and reduce the period of time over which some existing development can remain relatively safe. As noted in *Governing California through Climate Change*, "The notion of stable, predictable geography in which to live, work and build permanent buildings will be off the table in decades ahead" (Little Hoover Commission 2014, p. 2). Locations that might have seemed relatively safe from erosion or flooding 20 or 30 years ago may now be shown to have greater vulnerability due to sea level rise. Sites that might have seemed safe for 80 or 100 years might now only be safe for 40 or 50 years.

As coastal change accelerates, it will become more apparent that development close to the coast cannot be treated in the same way as more inland development, where hazardous conditions may be less dynamic. Coastal dynamics have long been part of land use planning considerations and project design; however, the focus on this change will grow in importance with rising sea level. This may mean that as properties are evaluated for proposed development, the type and intensity of the proposed development may need to change to address the dynamic nature of the property and changing nature of the hazards. As coastal areas erode, the carrying capacity of the area may need to be revised. The trend of redeveloping with additions and larger structures may need to change to one of maintaining what is there or redeveloping with smaller structures that better suit site constraints. The changing expectations are an important aspect of sea level rise adaptation

and are an important part of the following discussions on how to include sea level rise in Local Coastal Programs, applications for Coastal Development Permits, and adaptation planning.

Sea level rise is one of many climate change effects that will have impacts on coastal resources and development along the California coast. Accelerated coastal erosion, changing precipitation patterns, increasing temperatures, and more extreme storms will pose planning challenges in concert with sea level rise. There are other climate change impacts in the coastal zone, such as changes in water supply, terrestrial habitats, and fire hazards, that are also important to consider in decision making, and the Commission intends to provide guidance on a range of anticipated climate change impacts in the future.

Chapter 2

Principles for Addressing Sea Level Rise in the Coastal Zone

This chapter summarizes the Coastal Commission's framing principles for addressing sea level rise, many of which derive directly from the requirements of the Coastal Act. These principles broadly lay out the common ideas and a framework by which sea level rise planning and permitting actions can be assessed, and as such, represent the goals to which actions should aspire. Individual actions and outcomes may vary based on a variety of factors, including applicable policies and location- or project-specific factors that may affect feasibility. There are four categories of principles: using science to guide decisions; minimizing coastal hazards through planning and development standards; maximizing protection of public access, recreation, and sensitive coastal resources; and maximizing agency coordination and public participation. Each category groups important and related concepts that are central to addressing the challenge of rising sea levels. Building on the cumulative knowledge and experience of the Commission, subsequent chapters of this Guidance use these principles to frame practical guidance for addressing sea level rise through planning and permitting decisions in the coastal zone, consistent with the statewide policies of the California Coastal Act as well as the statewide vision of climate resilience outlined in the 2014 *Safeguarding California* plan.

USE SCIENCE TO GUIDE DECISIONS [Coastal Act Sections 30006.5; 30335.5]

1. **Recognize and address sea level rise as necessary in planning and permitting decisions.** Address sea level rise science in all applicable coastal management and decision-making processes, including Local Coastal Programs (LCPs), Port Master Plans (PMPs), Public Works Plans (PWPs), Long Range Development Plans (LRDPs), Coastal Development Permits (CDPs), federal consistency reviews, and other Coastal Act decision processes. Sea level rise should be addressed in both hazard analyses and identification of adaptation strategies/alternative analyses, consistent with the policies of the Coastal Act and LCPs as applicable[10].

2. **Use the best available science to determine locally relevant (context-specific) sea level rise projections and potential impacts for all Coastal Act planning processes, project design, and permitting reviews.** Sea level rise science continues to evolve, and some processes that are not fully understood (*e.g.*, ice sheet dynamics) could potentially have large effects on future sea level rise. At the time of this report's publication, the best available science on sea level rise in California is the 2012 National Research Council (NRC) Report, *Sea-Level Rise for the Coasts of California, Oregon and Washington: Past, Present, and Future* (NRC 2012) (See Table 2), as stated in the 2014 *Safeguarding California* document

[10] This Guidance document is intended to help implement the Coastal Act and LCPs in the context of sea level rise concerns. However, the standard of review for Commission actions remains the California Coastal Act or applicable certified LCPs. In particular, the recommendations of this Guidance do not constitute "enforceable policies" for purposes of CZMA federal consistency reviews. The enforceable policies for conducting federal consistency reviews will remain the policies of Chapter 3 of the Coastal Act. Also, for federal agency activities, the standard is consistency "to the maximum extent practicable," with Chapter 3, *i.e.*, federal agency activities must be fully consistent unless existing law applicable to the federal agency prohibits full consistency. See 15 CFR. §§ 930.32 and 930.43(d). However, the Commission looks at sea level rise as one part of determining the coastal effects from an activity through CZMA federal consistency reviews and the use of this Guidance by all parties should help determine what those coastal effects may be or how effects from sea level rise may be mitigated. Pursuant to 15 CFR § 930.11(h), implementation of this guidance would not be grounds for an objection (because it is not an "enforceable policy") but it might be one means that "would allow the activity to be conducted consistent with the enforceable policies of the program" in order to avoid an objection.

and the Ocean Protection Council's 2013 State of California Sea-level Rise Guidance Document. As discussed in greater detail in Chapter 3 of this Guidance, these projections should be used in a scenario-based analysis to identify potential local impacts from sea level rise, incorporating storms, extreme water levels, and shoreline change. Other authoritative sea level science and projections may also be used, in part or in full, provided they are peer-reviewed, widely accepted within the scientific community, and locally relevant.

The Commission will re-examine the best available science periodically and as needed with the release of new information on sea level rise.[11] In addition, Commission staff intends to submit a periodic status report to the Commission describing updates on the best available science and adaptation practices, and any potential recommended changes to the Guidance document.

Table 2. Sea Level Rise Projections for California[12] (NRC 2012)

TIME PERIOD*	NORTH OF CAPE MENDOCINO	SOUTH OF CAPE MENDOCINO	
by 2030	-2 – 9 in (-4 – +23 cm)	2 – 12 in (4 – 30 cm)	
by 2050	-1 – 19 in (-3 – + 48 cm)	5 – 24 in (12 – 61 cm)	
by 2100	4 – 56 in (10 – 143 cm)	17 – 66 in (42 – 167 cm)	

*with Year 2000 as a baseline

3. **Recognize and address scientific uncertainty using scenario planning and adaptive management techniques.** Given the uncertainty in the magnitude and timing of future sea level rise, particularly over longer time periods, planners and project designers should use scenario-based analysis to examine a range of possible shoreline changes and sea level rise risks to shape LCPs and other plans and project development designs. As appropriate, development projects, resource management plans, and LCP and other planning updates should incorporate an adaptive management framework with regular monitoring, reassessments, and dynamic adjustment in order to account for uncertainty.

[11] Major scientific reports include the release of the 2014 National Climate Assessment (Melillo *et al*.) and the 2013 IPCC 5th Assessment Report.

[12] The NRC Committee divided the Pacific coast for California, Oregon and Washington into two regions, north and south of Cape Mendocino, due to differences in tectonics that occur at this location. North of Cape Mendocino, land is rising as ocean plates descend below the North American plate at the Cascadia Subduction Zone. South of Cape Mendocino, the coast is subsiding (NRC 2012, p. 3). Humboldt Bay has not experienced the regional uplift that characterizes most of the coast north of Cape Mendocino, and instead has shown the highest subsidence recorded for the California coast. As a result, the projections for north of Cape Mendocino may not be appropriate for use in or near Humboldt Bay and the Eel River Estuary. Please see *Humboldt Bay: Sea Level Rise Hydrodynamic Modeling, and Inundation Vulnerability Mapping* (Northern Hydrology and Engineering 2015) for additional information on sea level rise projections for the Humboldt Bay region.

4. **Use a precautionary approach by planning and providing adaptive capacity for the highest amounts of possible sea level rise.** LCPs and CDPs should analyze the highest projections of sea level rise in order to understand the implications of a worst case scenario. In some cases, it may be appropriate to *design* for the local hazard conditions that will result from more moderate sea level rise scenarios, as long as decision makers and project applicants *plan* to implement additional adaptation strategies if conditions change more than anticipated in the initial design. Similar to the recommendation in the Ocean Protection Council's 2011 *State Sea-Level Rise Resolution*, the Commission does not recommend using values solely in the lower third of the NRC's projections as this does not give a full picture of the risks. Looking instead at both the high and low projections allows users to build an understanding of the overall risk sea level rise poses to the region or site.

5. **Design adaptation strategies according to local conditions and existing development patterns, in accordance with the Coastal Act.** Design adaptation strategies using best management practices for adaptation, and tailor the design to the specific conditions and development patterns of the area, in accordance with the Coastal Act and certified LCPs. LCPs should continue to serve as a key implementing mechanism for these adaptation strategies. Adaptation strategies should be evaluated for their ability to both minimize hazards and protect coastal resources.

MINIMIZE COASTAL HAZARDS THROUGH PLANNING AND DEVELOPMENT STANDARDS
[Coastal Act Sections 30253; 30235; 30001, 30001.5]

6. **Avoid significant coastal hazard risks to new development where feasible.** Section 30253 of the Coastal Act requires new development to minimize risks to life and property in areas of high geologic and flood hazard. The strongest approach for minimizing hazards is to avoid siting new development within areas vulnerable to flooding, inundation, and erosion, thus ensuring stable site conditions without the need for long-term financial and resource commitments for protective devices. Methods to direct new development away from hazardous locations are included in Chapter 7 of this Guidance.

7. **Minimize hazard risks to new development over the life of the authorized development.** Coastal Act Section 30253 requires that new development minimize coastal hazard risks without the use of bluff retaining or shoreline protection devices that would substantially alter natural landforms. When hazards from sea level rise cannot be avoided, new development should include provisions to ensure that hazard risks are minimized for the life of the development without shoreline protection, including through future modification, relocation, or removal when they become threatened by natural hazards, including sea level rise.

8. **Minimize coastal hazard risks and resource impacts when making redevelopment decisions.** LCPs should encourage and require, as applicable, existing at-risk structures to be brought into conformance with current standards when redeveloped. Improvements to existing at-risk structures should be limited to basic repair and maintenance activities and not extend the life of such structures or expand at-risk elements of the development, consistent with the Coastal Act.

9. **Account for the social and economic needs of the people of the state, including environmental justice; assure priority for coastal-dependent and coastal-related development over other development.** In planning and project development concerning sea level rise, assure that the social and economic needs of the people of the state are accounted for in accordance with Coastal Act Section 30001.5(b), with special consideration for working persons employed within the coastal zone (Coastal Act Section 30001(d)). Recognize that low-income communities are less equipped to prepare for and respond to the impacts of sea level rise and ensure that LCP and CDP decisions account for environmental justice concerns and include low-income persons and communities in planning efforts.

10. **Ensure that property owners understand and assume the risks, and mitigate the coastal resource impacts, of new development in hazardous areas.** Property owners should assume the risks of developing in a hazardous location (often referred to as internalizing risk). They should be responsible for modifying, relocating or removing new development if it is threatened in the future. Any actions to minimize risks to new development should not result in current and/or future encroachment onto public lands or in impacts to coastal resources inconsistent with the Coastal Act. LCPs and Coastal Development Permits should require recorded assumptions of risk, "no future seawall" conditions, and/or other appropriate mitigation measures to internalize risk decisions with the private land owner.

MAXIMIZE PROTECTION OF PUBLIC ACCESS, RECREATION, AND SENSITIVE COASTAL RESOURCES [Coastal Act Chapter 3 policies]

11. **Provide for maximum protection of coastal resources in all coastal planning and regulatory decisions.** New and existing development, redevelopment, and repair and maintenance activities as well as associated sea level rise adaptation strategies should avoid or minimize impacts to coastal resources, including public access, recreation, marine resources, agricultural areas, sensitive habitats, archaeological resources, and scenic and visual resources in conformity with Coastal Act requirements. Impacts from development and related activities should be avoided or minimized; unavoidable impacts should be mitigated as necessary.

12. **Maximize natural shoreline values and processes; avoid expansion and minimize the perpetuation of shoreline armoring.** If existing development (both private and public) is threatened by sea level rise hazards, it should employ the least environmentally damaging feasible alternatives and minimize hard shoreline protection. Priority should be given to options that enhance and maximize coastal resources and access, including innovative nature-based approaches such as living shoreline techniques or managed/planned retreat. If traditional hard shoreline protection is necessary and allowable under the Coastal Act, use the least-environmentally damaging feasible alternative, incorporate projections of sea level rise into the design of protection, and limit the time-period of approval, for example, to the life of the structure the device is protecting. Major renovations, redevelopment, or other new development should not rely upon existing shore protective devices for site stability or hazard protection. Where feasible, existing shoreline protection that is no longer being relied upon in this way, or no longer needed otherwise, should be phased out.

13. **Recognize that sea level rise will cause the public trust boundary to move inland. Protect public trust lands and resources, including as sea level rises. New shoreline protective devices should not result in the loss of public trust lands.** Where allowed under the Coastal Act or the relevant LCP, shoreline protective devices should be sited, designed, and conditioned to ensure that they do not result in the loss of public trust lands[13] or encroach onto public trust lands without the permission of the appropriate trustee agency. When sea level rise causes the public trust boundary to move inland such that a protective device that was located on uplands becomes subject to the public trust, the permittee should either obtain permission from the appropriate trustee agency for the encroachment or apply for a permit to remove any encroachments.

14. **Address potential secondary coastal resource impacts (to wetlands, habitat, agriculture, scenic and visual resources, *etc.*) from hazard management decisions, consistent with the Coastal Act.** Actions to address sea level rise in LCPs or permits should not exacerbate other climate-related vulnerabilities or undermine conservation/protection goals and broader ecosystem sustainability. For example, siting and design of new development should not only avoid sea level rise hazards, but also ensure that the development does not have unintended adverse consequences that impact sensitive habitats or species in the area.

15. **Address the cumulative impacts and regional contexts of planning and permitting decisions.** Sea level rise will have impacts at both the site-specific and regional scales. In addition to the evaluation of site-specific sea level rise impacts, LCPs and projects should include an evaluation of the broader region-wide impacts, in two different contexts. First, the LCP or project should consider how sea level rise impacts throughout an entire littoral cell or watershed could affect the LCP jurisdiction or project. Second, the LCP or project should consider how options to adapt to sea level rise could result in cumulative impacts to other areas in the littoral cell or watershed. Actions should be taken to minimize any identified impacts.

16. **Require mitigation of unavoidable coastal resource impacts related to permitting and shoreline management decisions.** Require mitigation for unavoidable public resource impacts over the life of the structure as a condition of approval for the Coastal Development Permit. For example, for impacts to sand supply or public recreation due to armoring and the loss of sandy beach from erosion in front of shoreline protection devices, require commensurate in-kind mitigations, a sand mitigation fee, and other necessary mitigation fees (for example, public access and recreation mitigation). Because the longer term effects can be difficult to quantify, especially given uncertainty about the exact rate of future sea level rise, consider requiring periodic re-evaluation of the project authorization and mitigation for longer term impacts.

[13] The State holds and manages all tidelands, submerged lands, and beds of navigable waterways for the benefit of all people of the State for statewide purposes consistent with the common law Public Trust Doctrine ("public trust"). In coastal areas, the landward location and extent of the State's trust lands are generally defined by reference to the ordinary high water mark, as measured by the mean high tide line. Public trust uses include such uses as maritime commerce, navigation, fishing, boating, water-oriented recreation, and environmental preservation and restoration.

17. **Consider best available information on resource valuation when planning for, managing, and mitigating coastal resource impacts.** Planning, project development, and mitigation planning should evaluate the societal and ecosystem service benefits of coastal resources at risk from sea level rise or actions to prepare for sea level rise. These benefits can include flood protection, carbon sequestration, water purification, tourism and recreation opportunities, and community character. Resource values can be quantified through restoration costs or various economic valuation models.

MAXIMIZE AGENCY COORDINATION AND PUBLIC PARTICIPATION [Coastal Act Chapter 5; Sections 30006; 30320; 30339; 30500; 30503; 30711]

18. **Coordinate planning and regulatory decision making with other appropriate local, state, and federal agencies; support research and monitoring efforts.** Given the multitude of sea level rise planning, research, and guidance efforts occurring in California, it is critical for agencies and organizations to share information, coordinate efforts, and collaborate where feasible to leverage existing work efforts and improve consistency. Additionally, since many sea level rise hazards affect multiple jurisdictions, their management may also need to be coordinated through multi-agency reviews and coordinated decision making. The Commission will continue to meet this goal through coordination, engagement with stakeholders, and trainings. However, ongoing financial support for these Commission efforts is critical.

19. **Consider conducting vulnerability assessments and adaptation planning at the regional level**. Where feasible, local governments should coordinate vulnerability assessments and adaptation planning with other jurisdictions in the region that face common threats from sea level rise. A regional vulnerability assessment provides an opportunity to evaluate impacts that span multiple jurisdictions, assess and implement regional adaptation strategies, coordinate responses, and leverage research and planning funds.

20. **Provide for maximum public participation in planning and regulatory processes.** The Coastal Commission will continue to provide avenues for maximum public participation in planning and regulatory processes, and will continue to establish and/or expand non-traditional alliances (*e.g.*, between/among public and private resource managers, tribal groups, scientists, decision makers), share knowledge openly and actively, and regularly and clearly communicate to the public on the science as well as on a range of solutions to prepare for sea level rise.

This document and its guiding principles both reflect and complement the priorities outlined in the State of California's climate adaptation strategy, the 2014 *Safeguarding California* plan. While this Guidance specifically focuses on the California Coastal Act and the regulatory work of the Coastal Commission, it also echoes key concepts in *Safeguarding California* that apply statewide. For example, a central theme in *Safeguarding California* is to provide risk reduction measures for California's most vulnerable populations, something that is addressed here in Guiding Principle #9. Similarly, this Guidance and *Safeguarding California* both emphasize the use of best available science (Guiding Principle #2) and the need for communication, outreach,

and public participation to increase understanding of climate risks and adaptation options (Guiding Principle #20).

Safeguarding California's Coast and Oceans chapter also states that "new development and communities must be planned and designed for long-term sustainability in the face of climate change," which captures a central purpose and focus of this Guidance. It goes on to specify that "California must ensure public access to coastal areas and protect beaches, natural shoreline, and park and recreational resources" and "the state should not build or plan to build, lease, fund, or permit any significant new structures or infrastructure that will require new protection from sea level rise, storm surges or coastal erosion during the expected life of the structure, beyond routine maintenance of existing levees or other protective measures, unless there is a compelling need." Again, these values are reflected here, as Guiding Principles #6 and #12. In these ways, and through the shared goal of ensuring planning for and resilience against climate change impacts, the two documents are readily consistent and complementary.

Chapter 3

Sea Level Rise Science

This chapter provides information on sea level rise science and covers the following subjects:

- The best available science on sea level rise
- Using scenario-based analysis in response to sea level rise projection ranges
- The physical impacts of sea level rise
- Storms, extreme events, and abrupt change

Sea level rise science continues to evolve, and the discussion below reflects the best available science at the time this document was published.

BEST AVAILABLE SCIENCE ON SEA LEVEL RISE

Scientists widely agree that the climate is changing and that it has led to global increases in temperature and sea level. In the past century, global mean sea level (MSL) has increased by 7 to 8 in (17 to 21 cm; IPCC 2013). It is extremely likely (>95% probability of occurrence) that human influence has been the dominant cause of the observed warming of the atmosphere and the ocean since the mid-20th century (IPCC 2013).

There are a number of methods for projecting future changes in global sea level, including using extrapolations from historical trends and observations, estimations from physical models, and combinations of observations and modeling, known as semi-empirical methods. For a detailed description of these techniques, see Appendix A.

Scientists also measure sea level change at a variety of scales, from the global down to the local level. For example, the sea level rise projections in Intergovernmental Panel on Climate Change (IPCC) reports are based on large scale models that give global projections. But sea level does not change uniformly around the globe, so modifications for local conditions are necessary for adaptation planning.

In particular, global average sea level rise is driven by the expansion of ocean waters as they warm, the addition of freshwater to the ocean from melting land-based ice sheets and glaciers, and from extractions in groundwater (Figure 3). However, regional and local factors such as tectonics and ocean and atmospheric circulation patterns result in relative sea level rise rates that may be higher or lower than the global average. As such, global-scale models are often "downscaled" through a variety of methods to provide locally relevant data.

For California, the National Research Council (NRC) 2012 report, described below, provides sea level rise projections that have been refined for the regions North and South of Cape Mendocino. Except for Humboldt Bay and the Eel River Estuary, more detailed refinement of sea level rise projections is not considered necessary at this time. While some, more localized refinements are possible, these local refinements are highly technical and data-intensive, and local variation from the regional projections will often be quite small. It is important to note, though, that while the sea level rise projections are fairly similar throughout the state, the physical impacts may be quite different, and locally-specific analysis of impacts will be very important. Detail on physical impacts and how to assess them is provided in Section C of this chapter and in Appendix B.

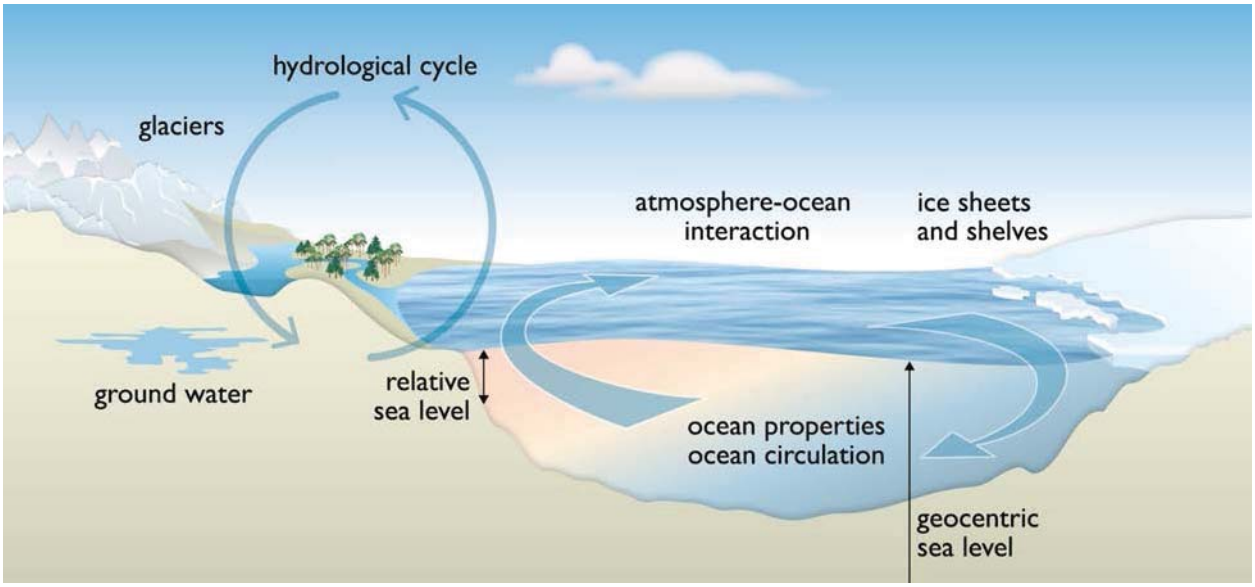

Figure 3. Climate-sensitive processes and components that can influence global and regional sea level. Changes in any one of the components or processes shown will result in a sea level change. The term "ocean properties" refers to aspects such as temperature, salinity, and density, which influence and are dependent on ocean circulation. (*Source*: IPCC 2013, Figure 13.1)

Global Sea Level Rise Projections

The IPCC 5th Assessment Report (AR5), which was released in September 2013, is the most recent global scale assessment of sea level rise. The report projects a rise in *global* average sea level by 10-39 in (26 to 98 cm) by the year 2100 (relative to mean sea level from 1985 to 2005) depending on the emissions scenario[14] (Figure 4). These projections are about 50% higher than the projections from the IPCC 4th Assessment Report (AR4, released in 2007). This is because the IPCC changed the climate model inputs between AR4 and AR5. In particular, much of the increase in the amount of sea level rise projected in the AR5 is due to the inclusion of sea level rise resulting from the loss of ice sheets. Ice sheet dynamics were not included in the AR4, but enhancements in physical models that account for such ice sheet dynamics have allowed for a better understanding and greater confidence in this input, and as such were included in the AR5[15].

[14] See Appendix A for more detail on emissions scenarios and the IPCC reports.

[15] Many of the other reports and studies cited in this Guidance used the AR4 as a reference (and for this reason detail on the AR4 is included in Appendix A). It is important to note, though, that while these other reports relied on the AR4 scenarios and model outputs for some climatic changes, many (*e.g.*, the *National Climate Assessment* (Melillo *et al*. 2014) and the NRC (2012) reports highlighted below) accounted for the loss of ice sheets through the use of semi-empirical models or other methods, further honing their results.

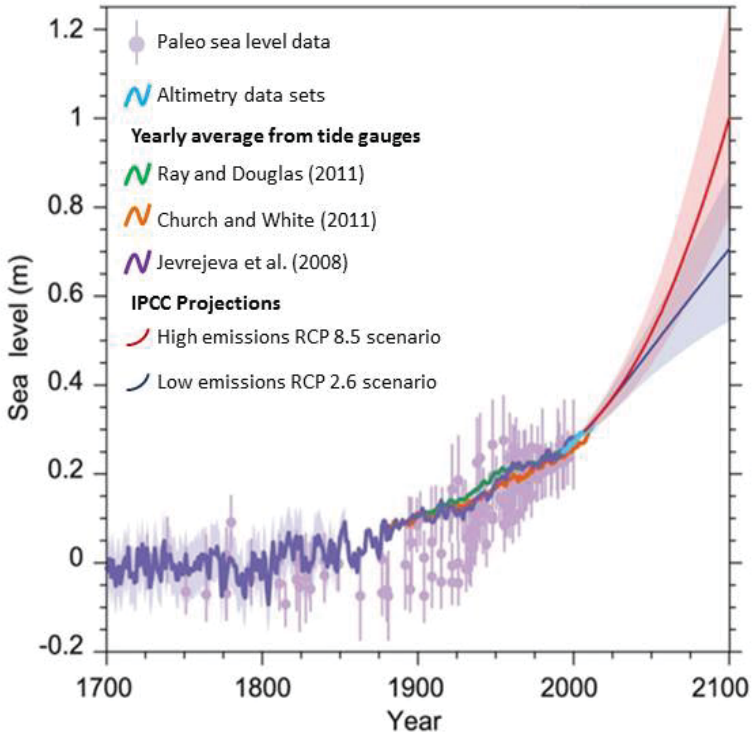

Figure 4. Past and projected future sea level trends (IPCC). Compilation of paleo sea level data, tide gauge data, altimeter data, and central estimates and likely ranges for projections of global mean sea level rise for low emissions RCP2.6 (blue) and high emissions RCP8.5 (red) scenarios, all relative to pre-industrial values. (*Source*: IPCC 2013, Figure 13.27)

National Sea Level Rise Projections

The third National Climate Assessment (NCA; Melillo *et al*.) was released in May 2014, and includes the current best-available science on climate change and sea level rise at the *national* scale. The sea level rise projections in the NCA were informed by the 2012 NOAA report titled *Global Sea Level Rise Scenarios for the United States National Climate Assessment* (Parris *et al.* 2012). This report provides a set of four global sea level rise scenarios ranging from 8 in to 7 ft (0.2 to 2.0 m) by the year 2100 (using mean sea level in 1992 as a baseline) reflecting different amounts of future greenhouse gas emissions, ocean warming and ice sheet loss (Figure 5). The low and intermediate-low scenarios assume very significant reductions in greenhouse gas emissions, and limited changes in ocean warming and ice sheet loss. The intermediate-high scenario is based on the average of the high projections from semi-empirical models, which are based on the highest IPCC 4th Assessment Report (AR4; 2007) emissions scenario (A1FI).[16] The highest scenario (2.0 m) combines the IPCC AR4 projections with the maximum possible ice sheet melt that could occur by 2100. Given the recent studies that suggest that glacier and ice

[16] The IPCC emissions scenarios make assumptions about future changes in population growth, future economic growth and the introduction of clean and efficient technology. The A1FI scenario assumes continued intensive use of fossil fuels, high economic growth, and low population growth that peaks mid-century. The B1 scenario assumes significant reduction in fossil fuel use, an increase in clean technologies, and the same low population growth that peaks mid-century. The A1F1 yields the highest CO_2 emissions by 2100 and the B1 scenario yields the lowest.

sheet loss could contribute significantly to rising sea levels (*e.g.*, Rahmstorf 2007; Vermeer and Rahmstorf 2009; IPCC 2013; McMillan *et al*. 2014; Morlighem *et al*. 2014) and evidence that current greenhouse gas emissions are tracking with intermediate IPCC AR4 scenarios (Rahmstorf *et al*. 2012), the low and intermediate-low scenarios likely underrepresent future sea level rise unless demonstrable reductions in global greenhouse gas emissions occur soon.

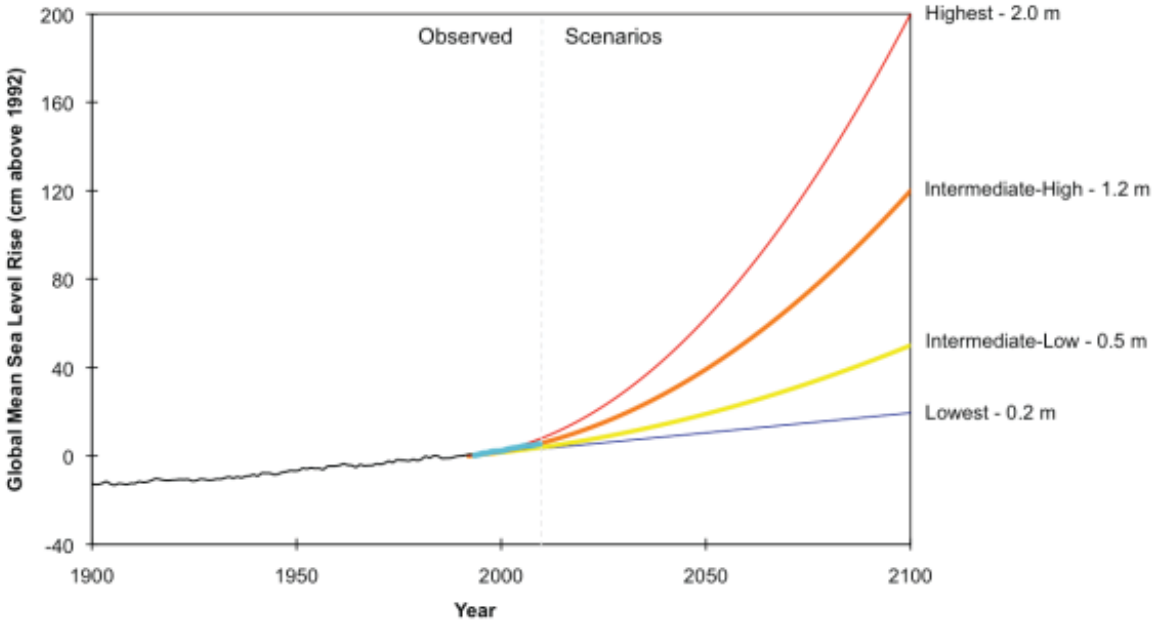

Figure 5. Observed and projected future sea level rise scenarios (Melillo *et al.* 2014). Global mean sea level rise scenarios used in the *US National Climate Assessment*. The Intermediate High Scenario is an average of the high end of ranges of global mean SLR reported by several studies using semi-empirical approaches. The Intermediate Low Scenario is the global mean SLR projection from the IPCC AR4 at 95% confidence interval. (*Source: Global Sea Level Rise Scenarios for the United States National Climate Assessment (*Parris *et al*. 2012))

Sea Level Rise Projections for California

Tide gauges and satellite observations show that in the past century, mean sea level in California has risen 8 in (20 cm), keeping pace with global rise. In the past 15 years or so, mean sea level in California has remained relatively constant, and may have been suppressed due to factors such as offshore winds and other oceanographic complexities. Bromirski *et al*. (2011, 2012) postulate that persistent alongshore winds have caused an extended period of offshore upwelling that has both drawn coastal waters offshore and replaced warm surface waters with cooler deep ocean water. Both of these factors could offset the global sea level rise trend in this region. However, localized sea level suppression will not continue indefinitely. As the Pacific Decadal Oscillation, wind, and other conditions shift, California sea level will continue rising, likely at an accelerated rate (NRC 2012; Bromirski *et al.* 2011, 2012).

Over the coming decades, sea level is projected to increase by 17 to 66 in (42 to 167 cm) along much of the California coast by Year 2100, according to the 2012 National Research Council *Sea-Level Rise for the Coasts of California, Oregon, and Washington: Past, Present, and Future* report. In March 2013, the Ocean Protection Council adopted a revised *State of California Sea-*

Level Rise Guidance Document that established the NRC 2012 report as the best available science on sea level rise for California (OPC 2013).[17]

The Commission will periodically re-examine and update sea level rise projections as they evolve with the release of new scientific reports and information on local and regional sea level trends. For now, however, the Commission recommends that local governments and applicants use the 2012 NRC report for the best available projections of regional sea level rise in California, though equivalent resources may be used by local governments and applicants provided the sources are peer-reviewed, widely accepted within the scientific community, and locally relevant.

The full range of sea level rise projections from the NRC report is provided below in Table 3. The range of sea level rise projections reflects uncertainties in future greenhouse gas emissions, future changes in the rate of ice sheet melt, and uncertainties related to the data. The low end of the range is based on the lowest IPCC 4th Assessment Report (AR4) future CO_2 emissions scenario (B1) and the high end is based on the highest IPCC AR4 emissions scenario (A1FI) (2007). Note that these amounts are what the NRC report refers to as "ranges." The report also includes "projections" that are based on the A1B emissions scenario. Please refer to Appendix A for a greater description of the "ranges" and "projections"[18]. Again, given current greenhouse gas emission levels and projections of future ice sheet loss, the lowest range of the sea level rise projections likely underrepresents future sea level rise (Rahmstorf *et al*. 2012; Horton *et al*. 2014).

Table 3. Sea Level Rise Projections for California (NRC, 2012)

TIME PERIOD*	NORTH OF CAPE MENDOCINO[19]	SOUTH OF CAPE MENDOCINO	
by 2030	-2 – 9 in (-4 – +23 cm)	2 – 12 in (4 – 30 cm)	
by 2050	-1 – 19 in (-3 – + 48 cm)	5 – 24 in (12 – 61 cm)	
by 2100	4 – 56 in (10 – 143 cm)	17 – 66 in (42 – 167 cm)	

*with Year 2000 as a baseline

The NRC report breaks the California coast into two regions – South of Cape Mendocino and North of Cape Mendocino. South of Cape Mendocino, much of the land is experiencing

[17] Visit www.opc.ca.gov/climate-change/ for the *State Sea-Level Rise Guidance Document.*

[18] Table 5.3 from the NRC 2012 report uses the term "projections" to refer to sea level rise amounts for the A1B emission scenario (herein referred to as the NRC A1B projection). However, unless otherwise noted, this Guidance uses the term "projections" to refer more generally to sea level rise amounts from the broad set of emission scenarios.

[19] Since portions of Humboldt Bay are experiencing subsidence, and thus differ from the regional uplift conditions, the projections for north of Cape Mendocino may not be appropriate for use within parts of Humboldt Bay. See Appendix B for additional discussion about vertical land movement and relative sea level rise.

subsidence, which will augment the consequences of rising sea level. For much of the area north of Cape Mendocino, the consequences of rising sea level are being reduced by the vertical land uplift along much of the Cascadia Subduction Zone. However, much of this vertical uplift could change rapidly during the next large Cascadian earthquake. During such an earthquake, areas north of Cape Mendocino could experience rapid subsidence of up to about 6 ft (2 m), which means relative sea level in the area would correspondingly rise (NRC 2012).

In contrast to the vertical uplift occurring throughout the majority of the area north of Cape Mendocino, Humboldt Bay's North Spit and the Eel River Estuary are subsiding and experiencing the highest rate of sea level rise in the state: a rate of 18.6 in over the last century (NOAA 2013). As a result, the projections for north of Cape Mendocino will not be appropriate for use in or near Humboldt Bay and the Eel River Estuary and will instead need to be modified to account for local vertical land movement. Please see *Humboldt Bay: Sea Level Rise Hydrodynamic Modeling, and Inundation Vulnerability Mapping* (Northern Hydrology and Engineering 2015) for additional information on sea level rise projections for the Humboldt Bay region.

The NRC report (2012) only provides estimated sea level rise ranges through the year 2100, though sea level will continue to rise, possibly at an accelerating rate, beyond the end of the century (IPCC 2013; Horton *et al*. 2014). Additionally, sea level rise in a particular location along the coast will likely vary from these regional projections due to changes in vertical land motion and ocean circulation, though such variation may be insignificant in places other than Humboldt Bay and the Eel River regions. Regardless, local governments, applicants, and staff may choose to modify these projections to account for local conditions and/or specific time periods, using the steps provided in Appendix B.

The Coastal Commission will be using and recommends that local governments and applicants use best available science, currently identified as the projections provided in the NRC 2012 report (Table 3), in all relevant local coastal planning and coastal development permitting decisions.

USING SCENARIO-BASED ANALYSIS IN RESPONSE TO SEA LEVEL RISE PROJECTION RANGES

Despite the recent advances in sea level rise science, sea level rise projections, including those in the 2012 NRC Report (Table 3) and the 2013 IPCC AR5, are typically presented in ranges due to several sources of significant uncertainty.

The two primary sources of uncertainty in *global* sea level projections include:

1) Uncertainty about future greenhouse gas emissions and concentrations of sulfate aerosols, which will depend on future human behavior and decision making, and
2) Uncertainty about future rates of land ice loss (NRC 2012; McMillan *et al*. 2014; Morlighem *et al*. 2014).

The NRC report (2012) also notes additional sources of uncertainty when projecting *regional* sea level for California, Oregon, and Washington, including:

1) Uncertainty in the influence of thermal expansion on local sea level, and
2) Uncertainty in future vertical land motion.

Additionally, the further into the future sea level rise is projected, the greater the uncertainty becomes. This occurs because the longer the projection period, the greater the likelihood that models will deviate from the actual impacts of climate change (NRC 2012).

This Guidance recommends using scenario-based analysis to address the uncertainty in sea level projections. Scenario-based analysis (or planning) refers to the idea of developing multiple scenarios from which to analyze vulnerabilities, generate new ideas and adaptation options, and/or test strategies. In the context of this Guidance, scenario-based analysis includes choosing several possible sea level rise amounts as a starting point to evaluate impacts to coastal resources and potential risks to development over time. This type of scenario-based approach is useful because it reveals the full range of possible consequences of sea level rise that can be reasonably expected for particular regions or sites according to the best available science. Additionally, a scenario-based analysis helps to reveal the tipping points indicating if or when sea level rise will become a serious issue in a particular location. In many cases, using multiple sea level rise scenarios will help to hone in on the types of hazards for which to prepare.

In general, the Coastal Commission recommends using best available science (currently the 2012 NRC report) to identify a range of sea level rise scenarios including the high projection, low projection, and one or more intermediate projections[20]. An even higher value than the NRC range might also be considered if there is the potential for severe impacts to coastal resources and human health and safety from sea level rise impacts. In practice, the process for choosing scenarios and performing scenario-based analysis will be slightly different for LCP planning and CDP applications due to the different planning goals and levels of technical detail required for each.

For a Local Coastal Program (LCP), the general goal is to assess the potential impacts from sea level rise over the entire planning area and over a range of time horizons so that both short and long term adaptation strategies can be identified and implemented. Another important facet of LCP planning is identifying locations that are particularly vulnerable so that additional, more detailed studies can be performed if necessary, and adaption options and actions can be prioritized. Scenario-based analysis in the context of LCP planning includes choosing a range of sea level rise projections to analyze so as to understand the best and worst case scenarios and to identify amounts of sea level rise and related conditions that would trigger severe impacts and the associated time period for when such impacts might occur. Choosing sea level rise scenarios in the context of LCP planning is described in greater detail in Chapter 5.

[20] Similar to the recommendation in the OPC's 2011 *State Sea-Level Rise Resolution,* the Commission does not recommend using values solely in the lower third of the NRC's projections as this does not give a full picture of the risks. Looking instead at both the high and low projections allows users to build an understanding of the overall risk sea level rise poses to the region or site.

In the context of a Coastal Development Permit (CDP) application, the goal is to understand how sea level rise will impact a specific site and a specific project over its expected lifetime so as to ensure that the proposed development is safe from hazards and avoids impacts to coastal resources. Thus, in the context of a CDP, it is important to identify the amounts of sea level rise that could result in effects to a particular site as well as the time period(s) over which those effects could occur so that the proposed development can be safely sited and designed to avoid resource and development impacts. However, some sites will be completely safe from sea level rise under even the highest projection scenarios, while others will depend on the timing and magnitude of sea level rise to determine safety. Therefore, scenario-based planning analysis can be used as a screening process to identify if and when sea level rise might become a problem. Identifying sea level rise scenarios in the context of CDPs is described in greater detail in Chapter 6.

Overall, scenario-based planning should help planners make reasonable and informed decisions about whether their projects or plans are compatible with the local hazards influenced by sea level rise, and identify the types of adaptation measures that might be appropriate given the local circumstances and requirements of the Coastal Act. By exploring the range of future scenarios based on the best available science, users of this document can make decisions based on full understanding of possible future hazards, ultimately achieve outcomes that are safer for both development and coastal resources, and avoid costly damages to projects.

For more information on scenario-based planning in the context of LCPs and CDPs see Chapters 5 and 6, respectively. A number of additional resources related to scenario-based planning are available, including a handbook from the National Park Service (2013) and guidance from Point Blue Conservation Science and the California Coastal Conservancy (Moore *et al*. 2013). See Appendix C for these and other resources related to scenario-based analysis and adaptation planning.

PHYSICAL EFFECTS OF SEA LEVEL RISE

Continued and accelerated sea level rise will have widespread adverse consequences for California's coastal resources (See summary in Figure 8). The main physical effects of sea level rise include increased flooding, inundation, wave impacts, coastal erosion, changes in sediment dynamics, and saltwater intrusion. These impacts are interrelated and often occur together. Absent any preparatory action, an increase in sea level may have serious implications for coastal resources and development, as described in Chapter 4. In addition, these physical effects could have disproportionate impacts on vulnerable communities that have lower capacity to adapt.

Physical effects from sea level rise to the coastal zone include the following:

- **Flooding and inundation:** Low lying coastal areas may experience more frequent flooding (temporary wetting) or inundation (permanent wetting), and the inland extents of 100-year floods may increase. Riverine and coastal waters come together at river mouths, coastal lagoons, and estuaries, and higher water levels at the coast may cause water to back up and increase upstream flooding (Heberger *et al*. 2009). Drainage systems that discharge close to sea level could have similar problems, and inland areas may become flooded if outfall pipes back up with salt water. In addition, other climate change impacts

such as increases in the amount of precipitation falling as rain rather than snow will add to river flooding in some areas.

- **Wave impacts:** Wave impacts can cause some of the more long-lasting consequences of coastal storms, resulting in high amounts of erosion and damage or destruction of structures. The increase in the extent and elevation of flood waters from sea level rise will also increase wave impacts and move the wave impacts farther inland. Erosion rates of coastal cliffs, beaches, and dunes will increase with rising sea level and are likely to further increase if waves become larger or more frequent (NRC 2012).
- **Erosion:** Large sections of the California coast consist of oceanfront bluffs that are often highly susceptible to erosion. With higher sea levels, the amount of time that bluffs are pounded by waves would increase, causing greater erosion (NRC 2012). This erosion could lead to landslides and loss of structural and geologic stability of bluff top development such as homes, infrastructure, the California Coastal Trail, Highway 1, and other roads and public utilities. The Pacific Institute (Heberger *et al*. 2009) estimated that 41 square miles (106 square km) of coastal land from the California-Oregon border through Santa Barbara County could be lost due to increased erosion with 4.6 ft (1.4 m) of sea level rise by the year 2100, and approximately 14,000 people now live in those vulnerable areas. Increased erosion will not occur uniformly throughout the state. Mendocino and Humboldt Counties have the greatest areas projected to be lost by erosion. For example, dunes in Humboldt County could erode a distance of approximately 2000 ft (nearly 600 m) by the year 2100 (Heberger *et al*. 2009; Revell *et al*. 2011). Man-made structures like dikes and levees may also be impacted by erosion, increasing flooding risk of the areas protected by those structures, such as low-lying agricultural land. Over the long term, rising sea levels will also cause landward migration of beaches due to the combined effects inundation and loss of sediment due to erosion (NRC 2012).

Figure 6. Photo of Esplanade Apartments threatened by cliff erosion in 2013 in Pacifica, CA. (*Source: California Coastal Records Project*)

- **Changes in sediment supply and movement:** Sediment is important to coastal systems in, for example, forming beaches and mudflats and as the substrate for wetlands. Sea level rise will result in changes to sediment availability. Higher water levels and changing precipitation patterns could change erosion and deposition patterns. Loss of sediment could worsen beach erosion and possibly increase the need for beach nourishment projects (adding sand to a beach or other coastal area), as well as decrease the effectiveness and long-term viability of beach nourishment if sand is quickly washed away after being placed on a beach (Griggs 2010). Sediment supplies in wetland areas will also be important for long-term marsh survival. Higher water levels due to sea level rise, however, may outpace the ability of wetlands to trap sediment and grow vertically (Titus 1988; Ranasinghe *et al*. 2012; Van Dyke 2012).
- **Saltwater intrusion:** An increase in sea level could cause saltwater to enter into groundwater resources, or aquifers. Existing research suggests that rising sea level is likely to degrade fresh groundwater resources in certain areas, but the degree of impact will vary greatly due to local hydrogeological conditions. Generally, the most vulnerable hydrogeological systems are unconfined aquifers along low-lying coasts, or aquifers that have already experienced overdraft and saline intrusion. In California, saline intrusion into groundwater resources is a problem in multiple areas, including but not limited to the Pajaro Valley (Hanson 2003), Salinas Valley (Hanson *et al*. 2002a; MCWRA 2012), Oxnard Plain (Izbicki 1996; Hanson *et al*. 2002b), and the heavily urbanized coastal plains of Los Angeles and Orange Counties (Edwards and Evans 2002; Ponti *et al*. 2007; Nishikawa *et al*. 2009; Barlow and Reichard 2010). Groundwater sources for coastal agricultural lands may also be susceptible to saltwater intrusion. Additional research is needed to understand the site-specific consequences of sea level rise and saltwater intrusion to these and other coastal aquifers in California.

STORMS, EXTREME EVENTS, AND ABRUPT CHANGE

Much of the California coast is currently vulnerable to flooding and wave damage during large storm events, and even more of the coast is vulnerable to storm impacts when they occur during times of heightened water levels, such as high tides, El Niño events, a warm phase of the Pacific Decadal Oscillation, or a combination of these factors. Sea level rise will increase coastal vulnerability to storms even more because rising water levels will result in more areas being impacted.

Climate change will likely modify or change much more than just sea level. One potential climate change-related impact that will interact most directly with sea level rise hazards is a change in frequency or intensity of coastal storms (storminess) and extreme events. The extremes associated with high-intensity events may be particularly devastating since they have the potential to cause broad-scale damage, as seen from recent events such as Hurricanes Katrina and Rita, Superstorm Sandy, and the Tohoku tsunami. Abrupt change in sea levels is another potential impact of climate change. Both potential impacts are described below.

Extreme Events and Storms

There are several ways to describe extreme events, and most definitions tend to frame these events in terms of consequences or past observations. Kruk *et al*. 2013 define extreme events as "the floods that displace us from our homes, the high waves that wash out coastal roads, or the toppling of trees and power poles from a passing storm." The IPCC defines climate extremes as "the occurrence of a value of a weather or climate variable above (or below) a threshold value near the upper (or lower) ends of the range of observed values of the variables" (IPCC 2012, p. 5). In general, extreme events, by their very nature, are those beyond the normal events that are considered in most shoreline studies. For example, for storm waves and flood conditions, an extreme event will normally be anything worse than the 100-year event.

Extreme events are of particular concern to the examination of coastal vulnerability and damage because they tend to cause the greatest community upheaval and can result in irreversible changes to the coastal landscape. In the El Niño winter of 1982-1983, for example, a series of storms, several of which coincided with high tide, caused more than $200 million in damage (in 2010 dollars) to coastal California (OPC 2013). The 2012 NRC report notes that "waves riding on these higher water levels will cause increased coastal damage and erosion—more than that expected by sea level rise alone" (NRC 2012, p.107). These impacts result because a rise in sea level will mean that flooding and damage will likely reach further inland. The IPCC *Fifth Assessment Report* (2013) states that it is very likely[21] that there will be a significant increase in the occurrence of future sea level extremes primarily as a result of an increase in mean sea level, with the frequency of a particular sea level extreme increasing by an order of magnitude or more in some regions by the end of the 21st century.

According to the 2012 NRC report, if the frequency or intensity of storms changes, then so will the frequency and intensity of extreme sea level events. However, the evidence that storminess will change in the North Pacific Ocean is conflicting and inconclusive (Cayan *et al*. 2009; Lowe *et al*. 2010; Dettinger 2011). Still, even if storminess does not change, sea level rise will exacerbate storm surge and high waves, magnifying their impact on the coastline. For this reason, it is important to include these factors in the analysis of sea level rise hazards. Methodologies for these analyses are included in Appendix B.

Abrupt change

Currently, the best available science is inconclusive as to whether sea level could change abruptly. Thermal expansion and direct melting of land ice is expected to be gradual, leading to slow and steady sea level rise. However, rapid collapse of land-based ice sheets could lead to sudden acceleration of sea level rise. Still, the likelihood of such collapses is uncertain (but probably low) and remains an area in need of future research (NRC 2013).

[21] The IPCC has assigned quantitative levels to various terms of confidence and likelihood. High confidence means there is about an 8 out of 10 chance of being correct. Very likely has a greater than 90% probability of occurrence. Other terms that will be used later in this discussion are likely (> 66% probability of occurrence), medium confidence (about a 5 out of 10 chance), low confidence (about a 2 out of 10 chance). *Source of terms*: http://www.ipcc.ch/pdf/supporting-material/uncertainty-guidance-note_ar4.pdf

Rapid change in land elevation during an earthquake is another potential cause of an abrupt sea level change in a localized area. A large earthquake in the Cascadia Subduction Zone could cause land in northern California, Oregon, and Washington to suddenly subside relative to sea level, causing a sudden rise in relative sea level by 3-6.5 ft (1-2 m; NRC 2012). Large earthquakes in this zone are expected to occur about every several hundred to one thousand years, and the most recent such earthquake occurred in 1700. The sudden rise or drop in land elevation would occur in a matter of minutes. If the land were to subside, the relative rise in sea level would be rapid and it would add to sea level rise already occurring from climate-related forcing.

There is also potential for oceanographic conditions to lead to a relatively rapid rate of sea level rise in California. Examination of the tidal gauge records indicate that there was no significant interannual rise in California's sea level from 1983 to 2011, despite a rise in global sea level over the same time period. One explanation, presented by Bromirski *et al*. (2011, 2012), links this suppression of sea level rise with persistent alongshore winds and an extended period of offshore upwelling that has both drawn coastal waters offshore and replaced warm surface waters with cooler deep ocean water. However, this suppression will not continue indefinitely and as the Pacific Decadal Oscillation, wind, and other conditions shift, California sea level will continue rising, likely at an accelerated rate (NRC 2012; Bromirski *et al.* 2011, 2012).

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Chapter 4

Consequences of Sea Level Rise for Communities, Coastal Resources, and Development

The physical effects of sea level rise described in the previous chapter could have significant consequences for California's citizens, coastal communities and the resources protected by the Coastal Act. This chapter describes some of these consequences and notes the relevant Coastal Act policies for convenience. It is important to consider both the direct impacts of sea level rise on coastal resources and what these impacts mean for the people and communities who use and enjoy these coastal resources. It is also important to consider environmental justice when analyzing sea level rise impacts, as described in greater detail in the section below.

SEA LEVEL RISE ADAPTATION PLANNING AND ENVIRONMENTAL JUSTICE

Sea level rise and how we respond to it may result in significant changes in the distribution of environmental benefits, or environmental justice, in California. General planning law in California specifically recognizes and defines environmental justice as "the fair treatment of people of all races, culture and income with respect to the development, adoption, implementation and enforcement of environmental laws, regulations, and policies" (Government Code Section 65040.12; and see Public Resources Code Section 71110-71116). Environmental justice demands that all people, regardless of their race, ethnicity, or level of income, are able to enjoy the benefits of our environmental protection programs and our environment generally. *Safeguarding California* (CNRA 2014) identifies environmental justice as an important cross-sector theme in the state's climate adaptation and resilience planning efforts.

The California Coastal Act also recognizes the fundamental importance of the fair distribution of environmental benefits in Section 30001:

> *The Legislature hereby finds and declares: (a) That the California coastal zone is a distinct and valuable natural resource of vital and enduring interest to all the people and exists as a delicately balanced ecosystem. (b) That the permanent protection of the state's natural and scenic resources is a paramount concern to present and future residents of the state and nation. (c) That to promote the public safety, health, and welfare, and to protect public and private property, wildlife, marine fisheries, and other ocean resources, and the natural environment, it is necessary to protect the ecological balance of the coastal zone and prevent its deterioration and destruction. (d) That existing developed uses, and future developments that are carefully planned and developed consistent with the policies of this division, are essential to the economic and social well-being of the people of this state and especially to working persons employed within the coastal zone.*

The Act thus declares that the protection of the coast is of vital interest to *all* the people, of paramount concern *to present and future residents* of the state and nation, and that careful planning and development is essential to *the economic and social well-being* of the people. This broad direction to protect the coast for everyone is underscored in Section 30006, which declares:

> *. . . the public has a right to fully participate in decisions affecting coastal planning, conservation and development; that achievement of sound coastal conservation and development is dependent upon public understanding and support; and that the continuing planning and implementation of programs for coastal conservation and development should include the widest opportunity for public participation.*

Hence, everyone is entitled to participate in the management decisions that determine how the benefits and burdens of managing California's coast will be distributed. Ensuring low-income and underserved communities are included in environmental decisions is a key tenet of environmental justice and will minimize disproportionate environmental and public health impacts.

The Coastal Act's broad concern for all the people is best borne out in its public access policies, which require the maximum provision and protection of the public's rights of access to and along the shoreline (Sections 30210-214). These policies reflect the judgement of the people of California in passing Proposition 20 in 1972 that public access and recreation along our coast is a fundamental environmental benefit to be protected for and enjoyed by all, not just by those with the good fortune or means to live along the shoreline. Public access to the coast is important to the health and well-being of the public, and promoting public access for all citizens provides low-cost, outdoor recreation that can improve the overall quality of life of the public, including low-income and underserved communities.

Unfortunately, public access is also one of the coastal resources most at risk from accelerating sea level rise. As discussed elsewhere in this Guidance, beaches, accessways, recreational amenities, and even surfing resources may be dramatically impacted by rising seas. Where development already exists, and particularly where there is substantial shoreline armoring to protect this development, California stands to lose significant recreational beach areas. These places that are at increased risk provide environmental benefits for everyone, generally at very low cost, or even free. Thus, the potential loss of beach and shoreline recreation areas represents a significant potential impact to a resource that both is especially important to those with fewer economic resources and one that we endeavor to provide for everyone without discrimination, no matter their income levels, ethnicities or cultures; no matter if they are from coastal or inland areas or from outside the state.

The exacerbation of environmental injustices by anticipated sea level rise may be particularly concerning when the Commission and local governments need to make decisions about shoreline protection and hazard mitigation. As discussed elsewhere in this Guidance, the Coastal Act provides for the protection and mitigation of coastal hazards for existing and new development. But some hazard mitigation, such as seawall development or elevated development on beaches, may have significant impacts to public trust shoreline resources. Thus, we face a situation where widely available public beach resources may be diminished in order to protect private or public development along the shoreline – potentially a significant environmental justice concern. Because of this, it will be important for decision makers to proactively consider all aspects of this Guidance in an effort to avoid and mitigate the potential impacts to coastal resources from hazard response. This is particularly true for recommendations to consider alternatives to shoreline structure development and, where shoreline structures must be approved, for recommendations to fully mitigate the impacts of such structures on public shoreline resources.

A May 2015 decision made by the Coastal Commission emphasizes the importance of analyzing low-cost recreational opportunities in addition to other coastal resource impacts when evaluating shoreline protection and other responses to sea level rise and coastal hazards. The Coastal Commission approved a revetment at the west end of the Goleta Beach County Park to provide

protection against erosion. This park is an important public resource in Santa Barbara County and receives up to 1.5 million visitors each year, a large fraction of which are low-income visitors. Park facilities include picnic areas, open parkland, and access to the ocean and a recreational beach for no or low cost. The revetment was approved contingent upon specific conditions, including continued free public access and vehicle parking for the term of the permit. This decision highlights the importance of protecting wide accessibility to shoreline resources even as sea level rises.

The potential impacts of adaptation responses on public shoreline resources, and thus the potential environmental justice impacts of such actions, will need to be considered for all resources protected under the Coastal Act. It is also true that due to current development patterns along the coast, sea level rise hazards may affect various sections of the population differently, as could the implementation and effectiveness of various adaptation measures. The number of people living along the open coast in areas exposed to flooding from a 100-year flood would increase to 210,000 with a 4.6 ft (1.4 m) increase in sea level; approximately 27% or 56,000 of these are lower income people (those earning less than $30,000 annually); 45,000 are renters; and 4,700 are linguistically isolated and less likely to understand flood warnings (Heberger *et al*. 2009). According to Heberger *et al*. (2009), the greatest increases in the number of people vulnerable to flooding will occur in Los Angeles, San Diego, Ventura, Humboldt, and San Luis Obispo counties. Sea level rise will likely result in the loss of key infrastructure, intrusion of saltwater into water sources, and the creation of additional coastal hazards. Hazards in vulnerable areas will have disproportionate impacts on communities with the least capacity to adapt, which could deepen and expand existing environmental injustice if adaptation responses are not managed appropriately.

For example, lower-income communities and those who live in rental units are more likely to be displaced by flooding or related impacts as compared to property owners because they lack the funds and/or abilities to rebuild, have less control over their safety, and often have limited access to insurance. Relatedly, these same populations are less likely to be able to take proactive steps to adapt to sea level rise. Additionally, loss of local public beaches or a reduction in public access and recreation opportunities would disproportionately affect low-income communities that have few alternative lower cost recreational opportunities. Tribal communities are also vulnerable to sea level rise because they are often tied to specific locations, and therefore can’t easily relocate.

Overall, it will be important for planners and decision makers to not only consider the direct impacts and consequences of sea level rise on coastal resources, but to also consider what those consequences mean for the distribution of environmental benefits along the coast, and the communities that use and rely on those resources. Low-income and underserved communities are less equipped to prepare for and respond to sea level rise, but community engagement and social cohesion can improve coastal resilience. Planners and decision makers should consider environmental justice concerns in the analysis of alternative project designs and adaptation measures and ensure low-income and underserved communities are involved in decision-making and planning efforts. This will better ensure that adaptation efforts benefit all Californians, fairly, and that they do not increase vulnerability to sea level rise among any particular group or demographic, and do not have any unintended consequences that lead to social or environmental

injustices. In particular, it will be important to consider the potential impacts of hazard mitigation actions to protect development that may only benefit a few, on the public access and shoreline resources that are available for all Californians to enjoy.

CONSEQUENCES OF SEA LEVEL RISE FOR COASTAL ACT RESOURCES

- **Coastal development (Coastal Act Sections 30235, 30236, 30250, 30253):** Sea level rise will increase the likelihood of property damage from flooding, inundation, or extreme waves, and will increase the number of people living in areas exposed to significant flooding. Increased erosion and loss or movement of beach sand will lead to an increase in the spatial extent of eroding bluffs and shorelines, and could increase instability of coastal structures and recreation areas. Levee systems could also experience damage and overtopping from an increase in water levels, extreme wave conditions, or a loss of wetlands, which buffer impacts from high water. The replacement value of property at risk from sea level rise for the California coast is approximately $36.5 billion (in 2000 dollars, not including San Francisco Bay) (Heberger *et al*. 2009).

  Impacts to public infrastructure, ports, and industrial development include:

  - **Public infrastructure:** Low-lying roads, wastewater treatment facilities, energy facilities, stormwater infrastructure, and utility infrastructure such as potable water systems and electricity transfer systems are at risk of impaired function due to erosion, flooding, and inundation. Heberger *et al*. (2009) estimated that 7 wastewater treatment plants, 14 power plants, including one in Humboldt County and 13 in Southern California, and 250 miles (402 km) of highways, 1500 miles (2414 km) of roads, and 110 miles (177 km) of railways could be at risk from a 100-year flood with 1.4-m rise in sea level (Heberger *et al*. 2009). Facilities and highways located on coastal bluffs subject to erosion will become more susceptible in the future. Sections of Highway 1 have already had to be realigned due to erosion or are in the planning stages for realignment projects, including areas in San Luis Obispo County, Monterey Bay, Half Moon Bay, and Marin County and the sections at risk in the future will likely increase.

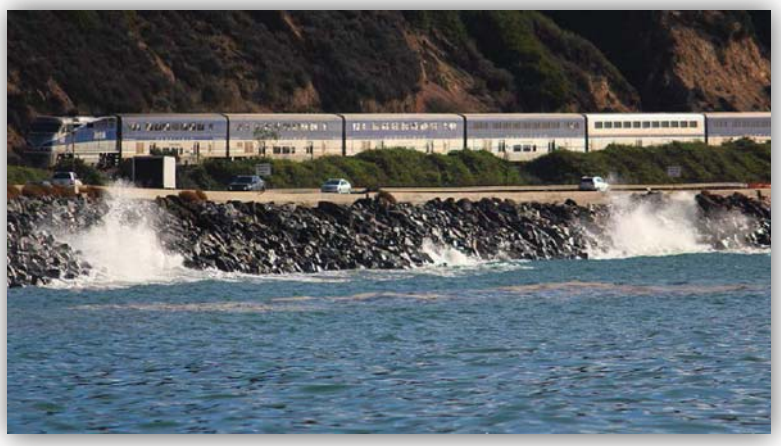

Figure 7. Photo of infrastructure at risk near Rincon Beach, Ventura, CA, during the King Tide in December 2012. (Photo courtesy of David Powdrell, California King Tides Initiative)

- **Ports (Coastal Act Sections 30703 – 30708):** Sea level rise could cause a variety of impacts to ports, including flooding and inundation of port infrastructure and damage to piers and marina facilities from wave action and higher water levels. A possible benefit could be a decreased need for dredging. But, unless facilities have already included accommodations for larger ships than they currently service, higher water levels could increase the difficulty for cargo handling facilities due to the higher vessel position (CCC 2001; CNRA 2014). Increased water heights could reduce bridge clearance, reducing the size of ships that can access ports or restricting movement of ships to low tides, and potentially increasing throughput times for cargo delivered to ports. Heberger *et al*. (2009) found that significant flooding from sea level rise is possible at the Ports of Los Angeles and Long Beach. Given that these two ports handle 45-50% of the containers shipped into the United States, and 77% of goods that leave the state, sea level rise could affect the efficiency of goods movement, and have serious economic implications for California and the nation (Heberger *et al*. 2009).
- **Industrial development, refineries, and petrochemical facilities (Coastal Act Sections 30260-30266.5):** Sea level rise could reduce areas available for siting or expansion of industrial development. Inundation of contaminated lands near industrial development could lead to problems with water quality and polluted runoff. Sea level rise could lead to an increase in flooding damage of refineries or petrochemical facilities, and impacts from sea level rise could be an issue when locating or expanding refineries or petrochemical facilities, or when mitigating any adverse environmental effects.
- **Construction altering natural shorelines (Coastal Act Section 30235):** Sea level rise may lead to an increase in demand for construction of shoreline protection for existing development, public access, and coastal-dependent uses in danger of erosion. Shoreline protection devices alter natural shorelines and also generally have negative impacts on beaches, near-shore marine habitat, and scenic and visual qualities of coastal areas.

- **Public access and recreation (Coastal Act Sections 30210, 30211, 30213, 30220, 30221):** One of the highest priorities in the Coastal Act is the mandate to protect and maximize public access to the coast. Sea level rise could lead to a loss of public access and recreational opportunities due to permanent inundation, episodic flooding, or erosion of beaches, recreational areas, or trails. In areas where beaches cannot migrate inland due to development or more resistant landforms, beaches will become narrower or will disappear completely. Access and functionality of water-oriented activities may also be affected. For instance, sea level rise, by increasing water levels and altering sediment patterns, could lead to a change in surfing conditions or affect the safety of harbors and marinas (Kornell 2012).
- **Coastal habitats (Coastal Act Sections 30230, 30231, 30233, 30240):** Coastal habitat areas likely to be affected by sea level rise include bluffs and cliffs, rocky intertidal areas, beaches, dunes, wetlands, estuaries, lagoons and tidal marshes, tidal flats, eelgrass beds, and tidally-influenced streams and rivers.

Importantly, there are many endemic and endangered species in California that are dependent on these coastal environments. For example, grunion need a sandy beach environment in order to reproduce and survive, the California clapper rail is dependent on marshes and wetlands, and the black abalone requires rocky intertidal habitat. Nesting habitat, nursery areas, and haul-out sites important for birds, fish, marine mammals and other animals could also disappear as sea levels rise (Funayama *et al*. 2012).

Impacts to wetlands, intertidal areas, beaches, and dunes include:

- **Beaches, dunes, and intertidal areas:** Inundation and increased erosion from sea level rise could convert habitats from one type to another and generally reduce the amount of nearshore habitat, such as sandy beaches and rocky intertidal areas. Sea level rise will cause landward migration of beaches over the long term, and could lead to a rapid increase in the retreat rate of dunes. Beaches with seawalls or other barriers will not be able to migrate landward and the sandy beach areas will gradually become inundated (NRC 2012). A loss of beach and dune areas will have significant consequences for beach and adjacent inland ecosystems. Beaches and dunes provide critical habitat for species and act as buffers to interior agricultural lands and habitat during storms (CNRA 2009).
- **Wetlands:** Sea level rise will lead to wetland habitat conversion and loss as the intertidal zone shifts inland. Of particular concern is the loss of saltwater marshes from sea level rise, which have already decreased by about 90% from their historical levels in California (CNRA 2010). California's 550 square miles (885 km) of critical coastal wetland habitat (Heberger *et al*. 2009, including wetlands in San Francisco Bay) could be converted to open water by 4.6 ft (1.4 m) rise of sea level if they are not able accrete upward or to migrate inland due to natural or anthropogenic barriers. Although barriers are plentiful, inland migration of these wetlands is possible for over 50% of the potentially inundated wetland area based on land use compatibility alone (Heberger *et al*. 2009). Consideration of adequate sediment supply and additional barriers to inland migration would further constrain wetland migration potential. A 4.6 ft (1.4 m) increase in sea level would flood 150 square miles (241 km) of land immediately adjacent to wetlands, which could become future wetlands if that land remains undeveloped. Loss or reduction of wetland habitat would impact many plant and animal species, including migratory birds that depend on these habitats as part of the Pacific Flyway. Species that are salt-tolerant may have an advantage as sea level rise occurs and exposes new areas to salt water, while species that have narrow salinity and temperature tolerances may have difficulty adapting to changing conditions.

o **Biological productivity of coastal waters (Coastal Act Sections 30230, 30231):** Sea level rise could affect biological productivity of coastal waters by changing the types of habitats that are available. This change could alter species composition, and could potentially result in cascading effects through the coastal food chain. Changes in water quality can have differing impacts on biological productivity. For instance, decreased water quality due to increased nutrient pollution has been found to increase biological productivity at the base of the food chain to undesirable levels, and has been linked to harmful algal blooms which result in hypoxic conditions for other marine species (Kudela *et al*. 2010; Ryan *et al.* 2010; Caldwell *et al*. 2013).

- **Water quality (Coastal Act Section 30231):** Sea level rise could lead to declines in coastal water quality in several ways. First, coastal water quality could be degraded due to inundation of toxic soils and an increase in nonpoint source pollution from flooding. In particular, the presence of facilities or land containing hazardous materials in coastal areas susceptible to flooding or permanent inundation presents toxic exposure risks for human communities and ecosystems. Second, rising seas could impact wastewater facility infrastructure and other methods and structures designed to protect water quality near the coast. In addition to damaging equipment and blocking discharge from coastal outfall structures, floods could force facilities to release untreated wastewater, threatening nearby water quality (Heberger *et al*. 2009). Salt water draining into sewer lines as part of extreme weather flooding might also damage biological systems at wastewater facilities if the organisms present in these systems are not salt-tolerant. Third, sea level rise could lead to saltwater intrusion into valuable groundwater aquifers, potentially rendering some existing wells unusable and decreasing the total groundwater supply in coastal areas. The extent of saltwater intrusion will likely vary based upon local hydrological conditions, with the worst impacts occurring in unconfined aquifers along low-lying coasts that have already experienced overdraft and saline intrusion. This change could force affected communities to turn to more costly water sources such as surface water transfers or desalination. Finally, loss of wetlands could decrease water quality given that wetlands act to improve water quality by slowing and filtering water that flows through them.
- **Coastal agriculture (Coastal Act Sections 30241- 30243):** Sea level rise could lead to an increase in flooding and inundation of low-lying agricultural land, saltwater intrusion into agricultural water supplies, and a decrease in the amount of freshwater available for agricultural uses. Flooding of agricultural lands can cause major impacts on local businesses, national food supplies, and the state's economy.
- **Archaeological and paleontological resources (Coastal Act Section 30244):** Archaeological or paleontological resources could be put at risk by inundation, flooding, or by an increase in erosion due to sea level rise. Areas of traditional cultural significance to California Native American tribes, including villages, religious and ceremonial locations, middens, burial sites, and other areas, could be at risk from sea level rise. For example, the Santa Barbara Channel area has thousands of archaeological sites dating over 13,000 years that are at risk of being destroyed or altered from small amounts of sea level rise (Reeder *et al*. 2010).

For a summary of some of the sea level rise impacts and potential consequences for the coast, see Figure 8. Many of these consequences are conditions that coastal managers already deal with on a regular basis, and strategies already exist for minimizing impacts from flooding, erosion, saltwater intrusion, and changing sediment patterns. Preparing for sea level rise involves integrating future projections of sea levels into existing hazard analyses, siting, design, and construction processes, ecosystem management, and community planning practices. Processes for integrating sea level rise in Local Coastal Programs and Coastal Development Permit applications are described in the following chapters.

Drivers of Global SLR

Expansion of ocean water as temperature increases

Addition of freshwater to the ocean from melting glaciers and ice sheets

Addition of freshwater to the ocean from groundwater extraction, use, and discharge

Drivers of Local/Regional SLR Variability

Vertical land movement

Oceanographic phenomena including El Niño Southern Oscillation (ENSO) and Pacific Decadal Oscillation (PDO)

Physical Impacts of SLR

Inundation (permanent wetting)

Flooding (temporary wetting)

Increased erosion and bluff collapse

Increased tidal prism

Increased wave heights and force

Increased saltwater intrusion

Change in sediment movement patterns

Summary of Consequences of SLR for Coastal Resources & Development

Coastal Development: Greater likelihood of tidal damage, flooding, inundation, and extreme waves, which could lead to loss of property or physical injury; instability from increased erosion and loss/movement of beach sand; increased areas exposed to a 100-year flood.

Public infrastructure: Low-lying roads, wastewater treatment facilities, energy facilities, stormwater infrastructure, potable water systems, and electricity transfer systems are at risk of inundation and flooding, and impaired function. Infrastructure located on eroding bluffs is also subject to increased geologic hazards.

Coastal Agriculture: Increase in flooding and inundation of low-lying agricultural lands; saltwater intrusion into agricultural water supplies; potential decrease in amount of freshwater available for agricultural uses.

Public Access & Recreation: Loss of beach areas where beaches cannot migrate inland due to development; inaccessibility of public accessways and recreation sites due to flooding and erosion.

Coastal Habitats: Transformation of habitats as intertidal zone shifts inland; loss of wetlands and other habitats where areas cannot migrate up or inland due to inland barriers such as coastal development.

Water Quality: Coastal water quality could decline due to inundation of toxic soils and an increase in nonpoint source pollution from flooding. Rising seas could also impact wastewater facilities and cause saltwater intrusion into groundwater supplies.

Biological productivity of coastal waters: Sea level rise could affect biological productivity of coastal waters by changing the types of habitats that are available. This change could alter species compositions, and could potentially result in cascading effects through the coastal food chain.

Cultural Resources: Archeological and paleontological sites, including many Native American villages, religious and ceremonial locations, burial sites, and other areas could be at risk from sea level rise.

Figure 8. Summary of sea level rise impacts and consequences

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Chapter 5

Addressing Sea Level Rise in Local Coastal Programs

The Coastal Act requires that the 61 cities and 15 counties in coastal California prepare Local Coastal Programs (LCPs) to govern land use and development in the coastal zone inland of the mean high tide. LCPs become effective only after the Commission certifies their conformity with the policies of Chapter 3 of the Coastal Act.

LCPs contain the ground rules for future development and protection of resources in the coastal zone. Each LCP includes a Land Use Plan (LUP) and an Implementation Plan (IP). The LUP specifies the kinds, locations, and intensity of uses, and contains a required Public Access Component to ensure that maximum recreational opportunities and public access to the coast is provided. The IP includes measures to implement the LUP, such as zoning ordinances. LCPs are prepared by local governments and submitted to the Coastal Commission for review for consistency with Coastal Act requirements.[22]

Once an LCP's certification becomes effective, the local government becomes responsible for reviewing most Coastal Development Permit (CDP) applications. However, the Commission retains continuing permit authority over some lands (for example, over tidelands, submerged lands, and public trust lands) and authority to act on appeals for certain categories of local CDP decisions.

To be consistent with the Coastal Act hazard avoidance and resource protection policies, it is critical that local governments with coastal resources at risk from sea level rise certify or update Local Coastal Programs that provide a means to prepare for and mitigate these impacts. The overall LCP update and certification process has not changed. Now, however, the impacts of accelerated sea level rise should be addressed in the hazard and coastal resource analyses, alternatives analyses, community outreach, public involvement, and regional coordination. This Guidance is designed to complement and enhance the existing LCP certification and update steps. Although the existing LCP certification and update processes are still the same, sea level rise calls for new regional planning approaches, new strategies, and enhanced community participation.

LCPs are essential tools to fully implementing sea level rise adaptation efforts. Since many existing LCPs were certified in the 1980s and 1990s, it is important that future amendments of the LCPs consider sea level rise and adaptation planning at the project and community level, as appropriate. The *California Climate Adaptation Strategy* (CNRA 2009) and *Safeguarding California* (CNRA 2014) specifically identify LCPs as a mechanism for adaptation planning along the California coast. For general guidance on updating LCPs, see the LCP Update Guide, available here: http://www.coastal.ca.gov/la/lcp.html.

[22] In addition there are other areas of the coast where other plans may be certified by the Commission, including Port Master Plans for ports governed by Chapter 8 of the Coastal Act, Long Range Development Plans for state universities or colleges, and Public Works Plans for public infrastructure and facilities. Following certification of these types of plans by the Commission, some permitting may be delegated pursuant to the Coastal Act provisions governing the specific type of plan.

Steps for Addressing Sea Level Rise in Local Coastal Programs and Other Plans

The Commission recommends the following six steps to address sea level rise as part of the development of an LCP, LCP Amendment, or other plan.[23] These steps can be modified and adapted to fit the needs of individual planning efforts and communities and to address the specific coastal resource and development issues of a community, such as addressing bluff erosion or providing for effective redevelopment, infill, and concentration of development in already developed areas. At the start of an LCP update to address sea level rise or a new LCP project, local government planners should contact their local Coastal Commission district office to discuss the LCP goals and to establish a plan for Coastal Commission staff coordination and public involvement throughout the entire process. A key element of any LCP project is public involvement. This can include establishing technical and community stakeholder advisory committees, establishing an interdepartmental sea level rise team of City and County staff representatives, and planning a series of public workshops to gather feedback, in addition to the required public hearings on the LCP.

The steps of this process are illustrated in Figure 9 and described below. They are similar to the standard steps of a long-range planning process and should be familiar to local planners. Steps 1-3 are often referred to as a "sea level rise vulnerability assessment" in other sea level rise planning contexts and therefore are similar to other sea level rise-related resources.

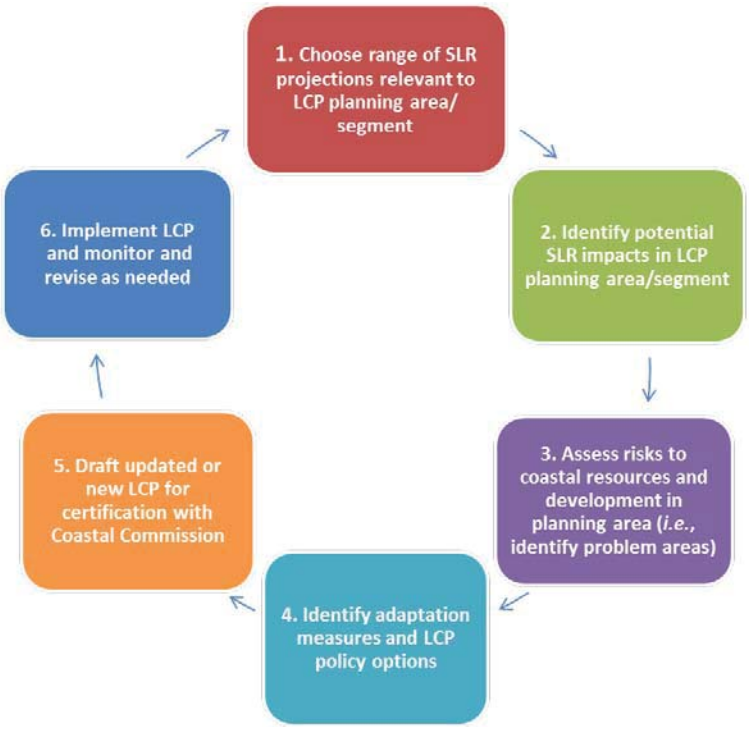
1. Choose range of SLR projections relevant to LCP planning area/ segment
2. Identify potential SLR impacts in LCP planning area/segment
3. Assess risks to coastal resources and development in planning area (*i.e.*, identify problem areas)
4. Identify adaptation measures and LCP policy options
5. Draft updated or new LCP for certification with Coastal Commission
6. Implement LCP and monitor and revise as needed

Figure 9. Sea level rise adaptation planning process for new and updated Local Coastal Programs

[23] This Guidance uses the term 'LCP process' to refer to the LCP process, but many of the concepts included here are applicable to other planning processes, including Long Range Development Plans, Public Works Plans, and Port Master Plans. For example, recommendations for how to analyze sea level rise impacts and perform a vulnerability assessment are broadly applicable. Many adaptation strategies may also be applicable, though in all cases, individual actions taken will vary based on relevant policies, local conditions, feasibility, and other factors.

The Coastal Commission also offers a *Local Coastal Program (LCP) Update Guide* (2013b) that outlines the broad process for amending or certifying an LCP, and there is naturally some overlap between the content of that document and this Sea Level Rise Policy Guidance document. The general LCP amendment steps are outlined below, in a flow chart (see Appendix D), and in the LCP Tips/Best Practices document (2013c), which is available in the *Resources for Local Governments* section of the Commission's website. Local governments should contact the Coastal Commission planner for their area when pursuing a new LCP or LCP amendment.

1. **Initial Amendment scoping and development:** Conduct issues assessment, identify need for amendment, prepare preliminary draft, coordinate with Commission staff, and share early drafts
2. **Local Amendment process:** Notify public, conduct local outreach and hearings, meet with Commission staff to discuss any issues, and adopt LCP at the local level
3. **Prepare Submittal:** assemble LCP materials, discuss with Commission staff prior to submittal, transmit to Coastal Commission, and make available to public
4. **Process Amendment at Coastal Commission:** Commission staff will review submittal within 10 working days for completeness; will address outstanding information needs; will prepare and write staff report; hold public hearing and vote; and transmit action to local government
5. **Effectuate Amendment:** Local acceptance of any modifications or resubmittal within 6 months, finalize local approval, and complete Coastal Commission Executive Director check-off
6. **Implement LCP Amendment, monitor and revise as necessary.**

The step-by-step process for incorporating sea level rise into LCPs outlined in the rest of this chapter fits into these broader LCP amendment steps. Local government planners should use the LCP Update Guide in conjunction with the Sea Level Rise Policy Guidance to inform the LCP.

Use scenario-based analysis

The Guidance recommends using a method called "scenario-based analysis" (described in Chapter 3 of this Guidance). Since sea level rise projections are not exact, but rather presented in ranges, scenario-based planning includes examining the consequences of multiple sea level rise amounts, plus extreme water levels from storms and El Niño events. The goal of scenario-based analysis for sea level rise is to understand where and at what point sea level rise, and the combination of sea level rise and storms, pose risks to coastal resources or threaten the health and safety of a developed area. This approach allows planners to understand the full range of possible impacts that can be reasonably expected based on the best available science, and build an understanding of the overall risk posed by potential future sea level rise. For example, if there are large changes in the hazard zones between two sea level rise amounts, additional analyses may help determine the tipping points when viable land uses will change. In general, scenario-based analyses can help determine the long-term compatibility of certain areas with certain land uses. For further description of this method, see Chapter 3.

Include other topics as applicable or desired

This Guidance recommends a number of analyses that will generate useful information related to sea level rise and other environmental vulnerabilities. Performing these analyses (and the overall planning process) may provide a useful opportunity to include other studies that will complement the goals of Local Coastal Programs and provide valuable insights for community concerns. For example, planners should expand the Coastal Act consideration of lower cost visitor serving facilities to include considerations of social equity and environmental justice in the analyses by determining how climate hazards or the adaptation measures might differentially impact various demographics. Additionally, planners may want to incorporate analysis of the economic implications of various options for adaptation. Important topics such as these should be incorporated into the analyses already underway for the sake of efficiency.

Leverage analyses and share information with other planning-related processes and documents

Sea level rise is addressed in many other planning-related documents and by many other agencies and organizations. Planners should be aware of these documents and the on-going work of state and federal agencies and make an effort to share information in cases where analyses required for some of these documents may overlap with the studies appropriate for sea level rise planning in LCPs. Additionally, these agencies, organizations, and planning efforts may be good resources from which to gather information when performing these analyses for LCP updates.

For example, there is overlap between the required elements of a Local Hazard Mitigation Plan (LHMP) and Local Coastal Programs, and the Commission recommends coordinating an LHMP update with an LCP update if possible. As part of an LHMP, local governments identify the natural hazards that impact their community, identify actions to reduce the losses from those hazards, and establish a coordinated process to implement the plan.[24] In order to be eligible for certain types of non-emergency disaster assistance, including funding for hazard mitigation projects, local governments are required by FEMA to complete an LHMP[25] and to update the plan every 5 years. Any sea level rise hazard avoidance strategies included in an LCP certification or update, such as relocation of critical facilities must be included in the LHMP narrative to be eligible for funding from FEMA to implement future projects. If a local government has recently updated their LHMP, the city or county can add narrative information on sea level rise strategies through an addendum to the plan, referred to by FEMA as an annex.[26]

In many cases, the analyses and adaptation options identified in this Guidance could be used for hazard mitigation plans or vice versa, as the goal of each of these planning processes is to

[24] http://www.fema.gov/media-library-data/20130726-1524-20490-5927/67fr8844.pdf

[25] Note that recent revisions to the State Mitigation Plan Review Guide, set to go into effect in March 2016, will require states to analyze the probability and possible impacts due to future hazard events in a way that includes the projected changes in natural hazards resulting from climate change. Failure to include such considerations may result in a state's ineligibility for certain non-emergency mitigation grants.

[26] For more information on how to complete or update an LHMP, visit http://hazardmitigation.calema.ca.gov/ or contact the Cal OES office and a hazard mitigation technical expert can assist local governments with the planning process. For contact information, visit http://hazardmitigation.calema.ca.gov/contact.

minimize or avoid impacts from coastal hazards. As a result, there may be opportunities to leverage funding and share work efforts.

A number of other similar planning processes, projects, and documents are listed in Figure 10, and planners may be able to use these studies in the LCP planning process, or, alternatively, share analyses and information performed for LCP planning with the groups working on related projects. Additionally, the forthcoming State of California Planning for Sea Level Rise Database (established by Assembly Bill 2516 and pursuant to Public Resources Code Sections 30961-30968) may become an important tool for identifying past and/or ongoing actions that stakeholders have implemented to address sea level rise. In any case, information sharing is highly recommended to promote efficiency.

Coordinate regionally as appropriate

Many impacts of sea level rise will transcend jurisdictional boundaries. Similarly, the adaptation decisions made by coastal communities could themselves have consequences that affect areas outside the local jurisdiction. For these reasons, regional coordination will often enhance the effectiveness of local adaptation decisions. Indeed, many of the projects identified in Figure 10 have taken this regional approach. Planners should keep this concept in mind as they work through these steps and coordinate regionally where appropriate and possible.

Representative Adaptation Planning Stakeholders

Agencies

Local/Regional:

- City/county governments
- League of Cities
- Association of Counties
- Regional entities (e.g., air districts, water boards, metropolitan planning organizations, regional transportation planning agencies)

State:

- Natural Resources Agency
- Ocean Protection Council
- CA Coastal Commission
- State Coastal Conservancy
- State Lands Commission
- SF Bay Conservation & Development Commission
- Office of Planning & Research
- Caltrans
- Office of Emergency Services
- CA Geologic Survey
- Dept. of Parks and Rec.
- Dept. of Fish and Wildlife
- Dept. of Water Resources
- State Water Resources Control Board
- Air Resources Board
- Dept. of Conservation

Federal:

- FEMA
- EPA
- US Fish and Wildlife Service
- NOAA
- Gulf of the Farallones NMS
- Monterey Bay NMS
- SF Bay NERR
- Elkhorn Slough NERR
- Tijuana River NERR
- US Geologic Survey
- US Army Corps of Engineers
- BOEM, BSEE
- National Park Service
- Sea Grant

Partner Organizations

- Non-Government Organizations (e.g., environmental, social)
- Professional organizations (e.g., agricultural, fisheries, communications)
- Science organizations
- Universities
- Private consultants/industry

Examples include:

- The Nature Conservancy
- Surfrider Foundation
- Coastkeeper Alliance
- Center for Ocean Solutions
- Point Blue Conservation Science
- Pacific Institute
- Natural Capital Project
- American Society of Adaptation Professionals

Coordinated Planning Efforts

Regional Environmental Efforts

- Our Coast Our Future (CoSMoS)
- So. CA Coastal Impacts Project (CoSMoS)
- Humboldt Bay SLR Adaptation Working Group
- Monterey Bay Adaptation Group
- LA Regional Adaptation Group
- Coastal Resilience Ventura
- San Diego Regional Climate Collaborative
- Santa Barbara and Ventura Co. resilience planning

Local/Regional Plans

- Local Hazard Mitigation Plans
- General Plans
- Climate Action Plans
- Capital Improvement Plans/Programs
- Climate Change Adaptation Plans
- Integrated Regional Water Management Plans
- Regional Sediment Management Plans
- Sustainable Community Plans
- Regional Transportation Plans

Figure 10. Agencies, organizations, and planning efforts related to sea level rise adaptation

Step 1 – Determine range of sea level rise projections relevant to LCP planning area/segment

The first step in incorporating sea level rise into the LCP planning process is to identify locally relevant sea level rise scenarios that may occur at given time steps into the future. These scenarios will be carried through the rest of the steps in the sea level rise LCP planning process. Follow these steps to determine the locally relevant sea level rise projections to use in the subsequent steps:

- **Determine planning horizons of concern:** The National Research Council (NRC) report for California uses the time periods of 2030, 2050, and 2100 to project future sea levels. These time periods may be used, or local governments may identify other relevant planning horizons for their plans and development scenarios, as long as the projections for those time frames are based on the best available and relevant scientific projections.

- **Determine the full range of sea level rise projections from the best available science:** Using best available science, currently the NRC report (or other comparable study, provided that it is peer reviewed, widely accepted within the scientific community, and locally relevant), determine the range of sea level rise for the planning horizons of concern. The sea level rise projections from the NRC 2012 report are presented in Table 4 below. If the planning horizon of concern extends past Year 2100, extrapolate from the NRC projections (See Appendix B for more details on this step). See below for a discussion of scenario-based planning in the LCP context. The LCP should include a policy to use the best available science about sea level rise.

  For parts of the Humboldt Bay region and Eel River Estuary, modify projections for vertical land motion:[27] For project locations in the vicinity of Humboldt Bay and the Eel River Estuary, the regional NRC sea level rise projections will need to be modified to adjust for local vertical land motion (VLM).[28] Areas other than Humboldt Bay and Eel River Estuary may choose to undertake an adjustment for vertical land motion. However, since local trends generally follow the regional land trend for most coastal areas, this VLM adjustment is not necessary.[29] Since actual VLM is the combination of several

[27] Vertical land motion describes the subsidence or uplift of land and is caused by different processes, including tectonic activity, sediment compaction, groundwater or other fluid withdrawal and recharge, and glacial isostatic rebound. Land North of Cape Mendocino is generally found to be rising at a rate of 1.5- 3.0mm/year, with the exception of parts of Humboldt Bay and the Eel River Estuary, which is subsiding. Land South of Cape Mendocino is subsiding at a rate of ~1mm/year, with variation in areas South of Cape Mendocino from -3.7 mm to 0.6 mm/year (NRC 2012, p. 78).

[28] See Appendix B and *Humboldt Bay: Sea Level Rise Hydrodynamic Modeling, and Inundation Vulnerability Mapping* (Northern Hydrology and Engineering 2015) for additional information on VLM and sea level rise projections for the Humboldt Bay region.

[29] A three-member subcommittee of the OPC Science Advisory Team (OPC-SAT) advised using the NRC projections, without modification, for all California locations except between Humboldt Bay and Crescent City. The OPC-SAT subcommittee stated, "We do not believe that there is enough certainty in the sea level rise projections nor is there a strong scientific rationale for specifying specific sea level rise values at individual locations along California's coastline" (OPC 2013, p. 10).

unrelated factors, such as seismic events, water withdrawals, and glacial isostatic rebound, historic trends may not be a good indicator of future change. Thus, if sea level rise projections are modified for areas other than the Humboldt Bay region and the modified projections are lower than the unmodified NRC projections, at least one scenario for the analysis of impacts should use the high value from the unmodified NRC projections in order to assess a potential worst-case scenario possibility.

Table 4. Sea Level Rise Projections for California (NRC 2012)

TIME PERIOD*	NORTH OF CAPE MENDOCINO	SOUTH OF CAPE MENDOCINO	
by 2030	-2 – 9 in (-4 – +23 cm)	2 – 12 in (4 – 30 cm)	
by 2050	-1 – 19 in (-3 – + 48 cm)	5 – 24 in (12 – 61 cm)	
by 2100	4 – 56 in (10 – 143 cm)	17 – 66 in (42 – 167 cm)	

*with Year 2000 as a baseline

- **Choose multiple sea level rise scenarios based on range of sea level rise projections.** The Coastal Commission recommends all communities evaluate the impacts of the highest water level conditions that are projected to occur in the planning area. Local governments may also consider including higher scenarios (such as a 6.6 ft (2 m) scenario[30]) where severe impacts to Coastal Act resources and development could occur from sea level rise. In addition to evaluating the worst-case scenario, planners need to understand the minimum amount of sea level rise that will cause impacts for their community, and how these impacts will change over time, with different amounts of sea level rise. Planners should evaluate enough scenarios to be able to answer the following:
    - What are the impacts from the worst-case scenario of the highest possible sea level rise plus elevated water levels from high tide, El Niño and a 100-year storm?
    - What is the minimum amount of sea level rise that causes inundation, flooding, or erosion concerns?
    - How do inundation, flooding, and erosion concerns change with different amounts of sea level rise?
    - Are there any tipping points where sea level rise impacts become more severe? (For example, is there a point at which seawalls or levees are overtopped?)

  There are two main ways to choose scenarios from which to evaluate sea level rise: by sea level rise amount or by time-period. Tools that provide maps by sea level rise amount can then be linked to the relevant time period, as shown below in the *Our Coast Our Future* example. There is no single accepted sea level rise mapping methodology for the

[30] The *Global Sea Level Rise Scenarios for the United States National Climate Assessment* (Parris *et* al. 2012) establishes 6.6 ft (2 m) as the highest global sea level rise scenario for Year 2100.

state of California. Local governments can choose whether to use existing sea level rise tools or to develop their own scenarios and maps. See below for information on scenarios and modeling outputs generated by existing sea level rise modeling tools.

Examples of Choosing Scenarios with Existing Sea Level Rise Modeling Tools

For California, there are two primary methods for identifying sea level rise scenarios, based on two of the currently available SLR mapping tools: CoSMoS (Our Coast Our Future) and Coastal Resilience Ventura (The Nature Conservancy). The type of tool available for sea level rise mapping in a planning area can be a deciding factor for which scenarios to use in the analysis. The Coastal Commission recommends using as many scenarios as necessary to fully analyze the potential impacts to coastal resources, human health, and safety rather than a specific tool or number of scenarios. Examples for choosing scenarios based on the tools available are described below.

Example 1: Identify SLR amounts, then relate to likely time period(s) of occurrence

This method involves first examining different amounts of sea level rise and storm events, and second, looking at the NRC projections to determine the range of years during which those impacts could potentially occur. For example, the Our Coast Our Future CoSMoS-based tool provides sea level rise maps for 9 different amounts in 25 cm (0.8 ft) intervals, three different storm scenarios (annual, 20-year, and 100-year), and a king tide scenario. With this tool, users can first evaluate different amounts of sea level rise and storms, determine how different amounts of sea level rise and storm situations affect the planning area, and then determine when the increased water level is likely to occur based on the NRC report projections. The CosMoS tool is currently available for Marin, Sonoma, and San Mateo Counties, and preliminary data will be available from Point Conception to the Mexico Border in Fall of 2015. The NOAA Sea Level Rise and Coastal Flooding Impacts viewer similarly provides maps for different amounts of sea level rise (in this case, in 1-ft increments), but does not include impacts from storms, erosion or waves. A methodology for adding in these additional impacts is described in Appendix B.

Example 2: Choose applicable years, then identify high, intermediate, and low scenarios

For this method, planners pick specific years, determine the range of sea level rise amounts that could occur by that year, and examine the consequences of three or more sea level rise amounts within that range. For example, the Coastal Resilience Ventura Tool (The Nature Conservancy) provides maps showing inundation, flooding, wave impact zone, and erosion risk zones with low, medium, and high sea level rise scenarios for the years 2030, 2060, and 2100. For local governments within Ventura County, planners may choose to evaluate scenarios according to the 2030, 2060, and 2100 time periods. The model provides maps for both flooding and erosion.

Expected outcomes from Step 1: *Upon completing this step, a range of regionally- or locally-relevant sea level rise projections for the time periods of concern should be established. Based on the range of projections, planners will have identified a low, high, and one or more intermediate projections. These projections are the sea level rise scenarios that will be carried through the rest of the planning process.*

Step 2 – Identify potential physical sea level rise impacts in LCP planning area/segment

The next step is to identify the physical hazards and impacts (referred to comprehensively as sea level rise impacts) associated with current and future sea level. As described in Section C of Chapter 3 of this Guidance, broad categories of sea level rise impacts may include inundation, flooding, wave impacts, erosion, and saltwater intrusion. In this step, planners should analyze these physical impacts and their various sub-components in order to understand current and future local hazard conditions. The analysis should answer the following basic questions:

- What are the existing hazard conditions that threaten the planning area?
- What is the projected change in hazard conditions due to locally appropriate sea level rise projections and planning horizons of concern?

This analysis should include the following topics, as applicable:

- Local Water Conditions (See Appendix B for a detailed methodology)
    - Current tidal datum[31] and future inundation
    - Water level changes from storm surge, atmospheric pressure, the Pacific Decadal Oscillation (PDO), the El Niño Southern Oscillation (ENSO), and/or other basin-wide phenomena
    - Wave impacts and wave runup, including wave runup from a 100-year storm, and based on tides, other water level changes, and future beach and bluff erosion
    - Flooding from extreme events such as storms with intervals greater than 100 years, tsunamis, *etc.*
- Shoreline change (See Appendix B for more information)
    - Current shoreline erosion rates. For future cliff and dune erosion rates, modify historic erosion rates, to account for the influence of sea level rise (*e.g.*, work by the Pacific Institute – Heberger *et al*. 2009; Revell *et al*. 2011). If possible, modify long-term beach erosion rates to account for changes in El Niño frequency, storm intensity, sediment supply or changing transport conditions. Analyzing wetland responses to sea level rise may require site-specific analyses of various physical and biological factors as described in Heberger *et al.* 2009.
    - Sedimentation rates
- Water quality
    - Current and future saltwater intrusion areas

[31] Tidal datums are based on the latest National Tidal Datum Epoch (NTDE) published by NOAA and are the mean of the observed sea levels over a 19-year period. The latest published epoch is 1983-2001. This tidal epoch can be considered equivalent to the year 2000 baseline for the NRC projections.

- Current and potential future coastal water pollution issues due to inundation of toxic soils, rising water tables, and increases in nonpoint source pollution

Use existing models, tools, reports, historic records, and other materials (Table 5) to develop or double check the identified hazard areas. Document the current and future hazard areas in the Land Use Plan using maps, GIS products, graphics, tables, charts, figures, descriptions, or other means. This process should be repeated for each planning horizon and/or sea level rise scenario defined in Step 1.

Expected outcomes from Step 2: *Upon completing this step, the potential current and future impacts to the planning area from sea level rise hazards should be identified based on sea level rise projections. These should include impacts from the high, low, and intermediate sea level rise scenarios for the planning horizon(s) of concern. Maps, GIS layers, graphics, figures, charts, tables, descriptions, or another system should be developed to communicate the impacts of current and future hazards.*

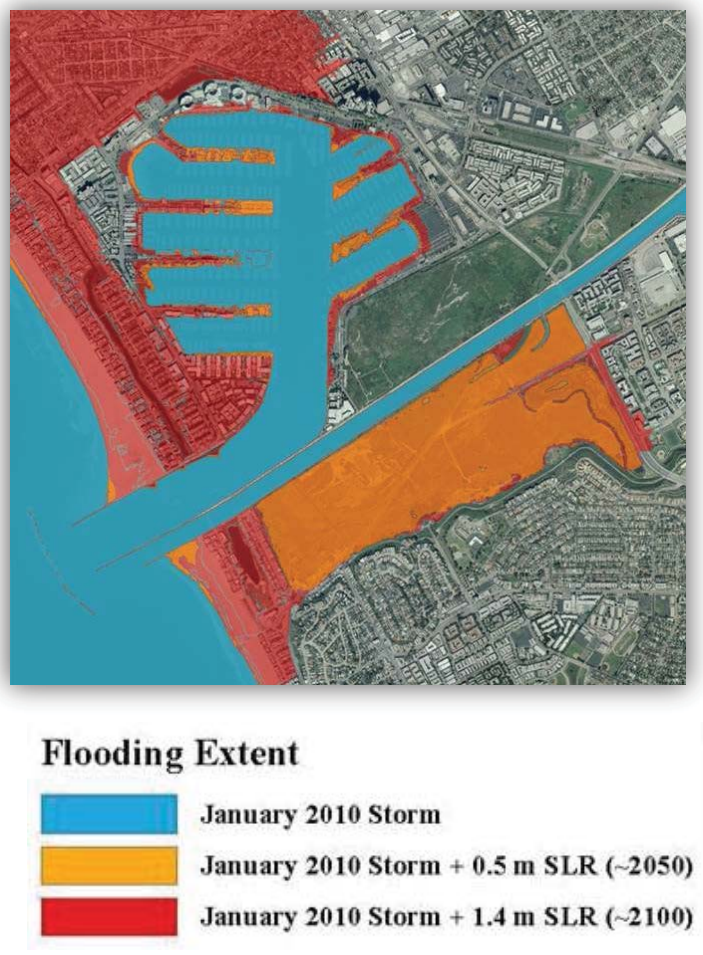

Figure 11. Example of analysis of SLR impacts. Flooding hazards predicted from the CoSMoS hindcast of the January 2010 storm, with and without sea level rise (SLR) scenarios, in the region of Venice and Marina del Rey, CA. (*Source*: Barnard *et al.* 2014).

Resources for Sea Level Rise Mapping

Table 5 includes a list of sea level rise mapping tools. The tools vary in their complexity: some are considered "bathtub models," because they show future inundation with simple rise in sea level (and no changes to the shoreline caused by other forces). Others include factors like erosion, storms, and fluvial inputs. These tools provide a useful first look at possible sea level rise impacts, but may need to be supplemented with additional, site- or topic-specific analyses, depending on the region. See Appendix B for additional information on determining hazard impacts and tools for mapping sea level rise.

Table 5. Sea Level Rise Mapping Tools

Tool	Description	Link
Statewide		
NOAA Sea Level Rise and Coastal Flooding Impacts Viewer	Displays potential future sea levels with a slider bar. Communicates spatial uncertainty of mapped sea level rise, overlays social and economic data onto sea level rise maps, and models potential marsh migration due to sea level rise. Maps do not include any influence of beach or dune erosion.	NOAA Office for Coastal Management, http://coast.noaa.gov/digitalcoast/tools/slr
Cal-Adapt – Exploring California's Climate	Shows coastal areas that may be threatened by flooding from a 4.6 ft (1.4 m) rise in sea level and a 100-year flood event. Maps were developed using the Pacific Institute SLR Maps (see below) and do not currently include any influence of beach or dune erosion or existing protective structures.	http://cal-adapt.org/sealevel/
Pacific Institute Sea Level Rise Maps	Downloadable PDF maps showing the coastal flood and erosion hazard zones from the 2009 study. Data are overlaid on aerial photographs and show major roads. Also available are an interactive online map and downloadable maps showing sea level rise, population and property at risk, miles of vulnerable roads and railroads, vulnerable power plants and wastewater treatment plants, and wetland migration potential.	http://www.pacinst.org/reports/sea_level_rise/maps/ For the 2009 report *The Impacts of Sea-Level Rise on the California Coast* visit: http://pacinst.org/publication/the-impacts-of-sea-level-rise-on-the-california-coast/

Climate Central Surging Seas	Overlays sea level rise data with socio-economic information and ability to analyze property values, population, socio-economic status, ethnicity, and income or areas at risk. Can compare exposure across the state or a county.	http://sealevel.climatecentral.org/ssrf/california
North Coast		
Humboldt Bay Sea Level Rise Adaptation Project	This project is a multi-phased, regional collaboration. Phase I produced the *Humboldt Bay Shoreline Inventory, Mapping, and Sea Level Rise Vulnerability Assessment* which describes current shoreline conditions and vulnerabilities under the current tidal regime. Phase II included hydrodynamic modeling to develop vulnerability maps of areas surrounding Humboldt Bay vulnerable to inundation from existing and future sea levels. Phase II produced the *Humboldt Bay Sea Level Rise Modeling Inundation Mapping Report* and the *Humboldt Bay Sea Level Rise Conceptual Groundwater Model*.	All reports are available at: http://humboldtbay.org/humboldt-bay-sea-level-rise-adaptation-planning-project
North Central Coast		
Our Coast Our Future Project (Bodega Head to Half Moon Bay), including the Coastal Storm Modeling System (CoSMoS)	Provides online maps and tools to help understand, visualize, and anticipate vulnerabilities to sea level rise and storms, including seamless Digital Elevation Model (DEM) at 6.6 ft (2 m) horizontal resolution; 9.8 in (25 cm) increment sea level rise projections between 0-6.6 ft (0-2 m) with a 16.4 ft (5 m) extreme; storm scenarios using the Coastal Storm Modeling System (CoSMoS); and interactive maps overlaying infrastructure and ecosystem vulnerabilities.	http://data.prbo.org/apps/ocof/

Southern Coast		
Coastal Resilience Ventura	A partnership to provide science and decision-support tools to aid conservation and planning projects and policymaking to address conditions brought about by climate change within the County of Ventura. The primary goals of Coastal Resilience Ventura are assessing the vulnerabilities of human and natural resources, and identifying nature-based solutions.	http://coastalresilience.org/geographies/ventura-county
Southern California Coastal Impacts Project, including the Coastal Storm Modeling System (CoSMoS)	A numerical modeling system to predict coastal flooding due to both sea level rise and storms driven by climate change; conditions will be specifically selected for and downscaled to the southern California region (from Point Conception to the US-Mexico border, including the Channel Islands and coastal embayments). This version will take into account shoreline change and fluvial inputs; additionally, even more robust modeling of coastal erosion and shoreline change will be provided for the Los Angeles region.	http://walrus.wr.usgs.gov/coastal_processes/cosmos/

Step 3 – Assess potential risks from sea level rise to coastal resources and development in LCP planning area/segment

After sea level rise impacts are identified and mapped in Step 2, the next Step is to determine whether sea level rise poses any risks, or potential problems, for coastal resources and development in the LCP planning area (refer to Chapter 4 for a description of the potential consequences of sea level rise for coastal resources). Next, assess whether the LCP planning area's current and planned land uses are appropriate or consistent with Coastal Act or LCP policies given those impacts, or if those land uses should be revised. This step requires an understanding of several characteristics of the coastal resources and development typically found within various land use types. (Much of this information can be produced in a vulnerability assessment, an analysis that is commonly conducted in the planning and climate change adaptation field. See Appendix C for a list of recent sea level rise vulnerability assessments.) Account for potential impacts to vulnerable, low-income communities and consider coastal development and resources, including but not limited to:

- Existing and planned development
- Coastal-dependent development and uses such as harbors, wharfs, ports, marinas, and commercial and recreational fishing areas and facilities
- Critical infrastructure[32] such as wastewater treatment plants, transportation infrastructure, and some power plants and energy transmission infrastructure
- Public accessways, beaches and other recreation areas, and the California Coastal Trail
- State Highway 1, 101, and other state and local roads that provide access to the coast
- Wetlands, environmentally sensitive habitat area (ESHA), and other coastal habitats and sensitive species
- Agricultural areas
- Cultural sites and archaeological or paleontological resources
- Visitor-serving development and uses

Conduct the following tasks for each planning horizon (*e.g.*, the years 2030, 2050, and 2100, or other planning horizons):

1. For the planning horizon of interest, determine what development and coastal resources may be subjected to the sea level rise impacts expected for that time period. Map the coastal resources and development that lie within the sea level rise impact areas for the given time period. (Remember to address the wide range of resources listed above, including both natural resources and development.)

[32] Critical infrastructure can vary widely from community to community. For planning purposes, a jurisdiction should determine criticality based on the relative importance of its various assets for the delivery of vital services, the protection of special populations, and other important functions.

2. Determine if sea level rise impacts are a problem or benefit for each resource, and if so, when and to what degree the resource will be impacted. In some instances, sea level rise may result in the creation of new habitat areas that could help to alleviate impacts from the loss of similar habitat in other locations. However, it is more likely, especially in heavily urbanized areas, that sea level rise will result in a net loss of habitat unless steps are taken to preserve these systems.

   To accomplish this, consider a wide range of characteristics of each resource, including the following. The questions listed under each characteristic might help guide the consideration of each of these characteristics. These questions are meant to be suggestions rather than a standardized approach, and planners may use scientific literature, best professional judgment, or a variety of other resources to gain a conceptual understanding of the important resources and vulnerabilities in their jurisdictions.

   a. **Exposure.** Will sea level rise impacts affect the resource/development at all?
      i. Are coastal resources and community assets exposed to sea level rise impacts?
      ii. Is the resource already exposed to hazards such as waves, flooding, erosion, or saltwater intrusion? If it is, will sea level rise increase hazard exposure?

   b. **Sensitivity.** If resources are exposed, to what degree will coastal resources/development be affected by sea level rise impacts? A simple way to think about this concept is to consider *how easily affected* the resource or development is in regard to sea level rise impacts.
      i. How quickly will the resource respond to the impact from sea level rise?
      ii. Will the resource/development be harmed if environmental conditions change just a small amount? What are the physical characteristics of resource/asset (*e.g.*, geology, soil characteristics, hydrology, coastal geomorphology, topography, bathymetry, land cover, land use)? Do any of those characteristics make the resource especially sensitive?
      iii. Are there thresholds or tipping points beyond which sensitivity to sea level rise increases?

   c. **Adaptive Capacity.** How easily can the resource successfully adapt to sea level rise impacts?
      i. How well can the resource/development accommodate changes in sea level?
      ii. Is rate of change faster than the ability of the resource/development to adapt?
      iii. How easily can development be modified to cope with flooding, inundation, and/or erosion? Can structures be elevated or relocated?

iv. Are there adaptation efforts already underway? Are there any factors that limit the success of adaptation efforts?

v. Do beaches, wetlands and other coastal habitats have room to migrate inland? What is the overall health of existing wetlands and coastal habitats?

vi. Are there any other climate change-related impacts to consider? Are there any non-climate stressors that could impair ability to adapt to sea level rise?

vii. Is there potential for habitat creation as a result of sea level rise?

viii. What are the options to protect, redesign (*e.g.*, elevate), or relocate inland any existing public accessways, recreational beaches, and segments of the Coastal Trail to cope with rising sea levels? Is lateral access compromised with sea level rise?

d. **Consequences.** When sea level rise and/or sea level rise adaptation measures have impact(s) upon a resource, what are the economic, ecological, social, cultural, and legal consequences?

i. How severely could each resource be affected? At what scale?

ii. Are there cumulative consequences?

iii. Are there ripple effects, or secondary consequences to consider?

iv. Will human responses cause further adverse impacts?

e. **Land Use Constraints.** Given the location of sea level rise impacts and the resources currently located in those areas, should the types and intensities of land use be altered to minimize hazards and protect coastal resources?

i. What is the current pattern of development? Is the area largely developed or does it have significant areas of undeveloped land?

ii. Is the area served by infrastructure that is vulnerable to sea level rise impacts?

iii. Are large areas of land under common ownership or is land mostly subdivided into smaller lots in separate ownership?

iv. What conditions does the land use type, development, or resource require to either exist or fulfill its intended purpose?

v. Is it a coastal-dependent use? What is its ideal proximity to the coast?

vi. For new development, what is the expected lifespan? Is it economically feasible to locate it in a sea level rise impact area for a certain period of time before it is removed or relocated?

vii. For existing development, what are the options available to minimize hazards to the development and protect coastal resources? Note that in

certain situations, the Coastal Act allows existing structures to be protected (Coastal Act Section 30235). What are the coastal resource impacts of such protection, and are there feasible alternatives that avoid shoreline armoring, such as options to provide incentives to property owners to relocate or remove at-risk structures?

viii. For a natural resource or habitat, what conditions does it require to persist?

ix. Where would resources/development ideally be located after sea level rise causes environmental conditions to shift?

x. What changes to existing LCP requirements or other land use restrictions are necessary to maximize opportunities for avoiding hazards or relocating threatened existing development?

After going through the questions listed above, and others that may be relevant to the planning exercise, synthesize the information and determine where sea level rise impacts currently pose problems for coastal resources, what problems may develop over time as sea level rises, and how urgent the problems are. Create maps illustrating the location and extent of vulnerable land uses, such as critical facilities, wastewater infrastructure, and State Highway 1 and other coastal access roadways. This information can also be summarized in narrative form. The analysis should identify resources and development likely to be impacted by sea level rise at various periods in the future, and thus the issues that need to be resolved in the LCP planning process.

Remember that these assessments are not static; existing risks will change and new risks will arise with changes in a community, the emergence of new threats, new information, and the implementation of adaptation actions. For this reason, the analysis should be updated as needed to reflect changes in sea level rise projections, changes in land use patterns, or new threats.

Expected outcomes from Step 3*: Descriptions of the characteristics that influence risk, including exposure, sensitivity, and adaptive capacity of each coastal resource to sea level rise impacts under each sea level rise scenario identified in Step 1 at the selected planning horizons, along with the expected consequences of those impacts for the resource and broader community. Maps of resources and/or land uses at risk could be produced.*

Example for Step 3

To illustrate the process described in Step 3, consider a hypothetical planning area that includes multiple coastal resources and land use types, including a coastal wetland, bluff-top residential development with a fronting beach, and a wastewater treatment facility, that need to be addressed in the planning process. After Steps 1 and 2, portions of the planning area are found to be subject to current and future sea level rise impacts.

Step 3.1: Map the coastal resources (in this case the wetland, development, and wastewater treatment facility) for the range of time periods and sea level rise projections.

Step 3.2

a. **Exposure**

- *Wetland:* The wetland is highly exposed to flooding and inundation from sea level rise. By the year 2030, portions of the wetland will trap sediment at a rate such that the elevation keeps pace with sea level rise. By 2050, a portion of the wetland will become inundated and converted to open water, and by 2100 the entire area will be converted to open water. The wetland will be completely lost by this time period if it is not able to move inland.
- *Bluff-top Residential Development:* Houses in the residential development are not exposed to sea level rise impacts in 2030. However, a high rate of retreat along the fronting beach and bluff will put front-line houses in danger of being undermined by the year 2050, and the entire development may be lost by 2100.
- *Wastewater Treatment Facility:* Given that the wastewater treatment plant is set back somewhat from the water, it will not be exposed to impacts from sea level rise until 2050. By 2050, however, portions of the infrastructure will be exposed to impacts from elevated water levels due to 100-year storm events and El Niño occurrences. By 2100, significant portions of the facility will be exposed to flooding as the surrounding area is eroded and inundated.

b. **Sensitivity**

- *Wetland:* The wetland has high sensitivity to changes in sea level because its functioning is highly-dependent on local physical parameters such as water flow, tidal fluctuation, sediment supply, and water quality. Although it currently has good sediment supply, good water quality, and a number of other characteristics, small changes in sea level rise by 2050 may alter the function of the wetland. In addition, there are concerns that beyond 2050 the wetland will not be able to keep up with accelerated sea level rise, thus increasing sensitivity to further changes in sea level.
- *Bluff-top Residential Development:* The residential development has moderate to high sensitivity to longer-term sea level rise changes. By 2050, the front-line houses will no longer be safe enough for occupancy. Moreover, infrastructure such as roads, sewage systems, and power networks may be damaged as the bluff-face erodes.
- *Wastewater Treatment Facility:* The facility is moderately sensitive to sea level rise. Flooding and erosion from sea level rise could cause damage of the facility, pumps and

other equipment, but the facility was initially built to withstand a high degree of storm and related impacts.

c. **Adaptive Capacity**

- *Wetland:* Unlike many wetlands in the State of California, this particular wetland has a moderate-high adaptive capacity because it has the ability to both accumulate sediment and grow upwards, and, given that the land upland of the wetland is preserved as open space, it can migrate inland. However, by 2050, a part or all of the existing wetland area could be converted to open water if the wetland is not able to migrate inland or accumulate sediment at a rate that keeps pace with sea level rise. In this case, for example, a public trail will need to be relocated to allow inland migration of the new intertidal zone. Additionally, adaptive capacity may be reduced if pollution increases (*e.g.*, as a result of damage to adjacent development) and disrupts the normal functioning of the wetland.
- *Bluff-top Residential Development:* The residential development has a moderate adaptive capacity. As houses become threatened over time, a scenario of managed retreat would allow houses to be removed incrementally and eventually be relocated to safer areas. The feasibility of managed retreat can depend upon lot sizes, ownership patterns, land use restrictions in the safer areas, and the availability of public or private financing. In addition, a protective structure such as a seawall would minimize threats to the residence due to erosion, though if the development is protected by shoreline structures, the fronting beach will eventually be lost.
- *Wastewater Treatment Facility:* The wastewater treatment facility has a very low adaptive capacity. It is large and has expensive infrastructure so it cannot be elevated, and relocation is costly and difficult. In order to be protected in its current location, new structures will need to be built.

d. **Consequences**

- *Wetland:* In many situations, the loss of wetland area is a high risk since wetlands provide flood protection, water quality enhancement, and essential habitat for fish and bird species. However, in this case, wetland migration is not restricted by inland development, so the risks for this wetland are slight to moderate, depending upon the suitability of the inland area for establishment of wetland plants and potential changes in water temperature and water quality. In the short term, the wetland will likely continue to function at normal levels. However, if it eventually can't keep up with sea level rise or if there are barriers to migration, loss of the habitat will result in a loss of important ecosystem services.
- *Bluff-top Residential Development:* The housing development has medium to high risk through 2100. The option to either relocate houses or protect them with a seawall means that they could continue to exist. Importantly, a system of managed retreat will allow for the continued existence of the fronting beach and all of its social, economic, and environmental benefits, whereas the construction of a seawall will result in the loss of the beach and these benefits.

- *Wastewater Treatment Facility:* Given its low adaptive capacity and high sensitivity to higher levels of sea level rise, the wastewater treatment facility is at high risk. Loss or damage to the facility could result in serious social, economic, and environmental consequences. Flooding of the facility and surrounding areas will cause damage to infrastructure and loss of facility function. This could lead to discharge of untreated sewage, which would have adverse impacts to water quality and could impair the health of nearshore ecosystems. Sea level rise could also cause outflow pipes to back up with seawater, leading to inland flooding and additional water quality problems. However, efforts to protect the structure may have unintended consequences including loss of surrounding habitat areas.

e. **Land Use Constraints (discussed further in Step 4)**

- *Wetland:* The high adaptive capacity of the wetland means that minimizing risk to this resource may be accomplished by ensuring that there is space available for it to move into. Land use policies designed to protect areas inland of the current wetland area will be necessary.
- *Bluff-top Residential Development:* The area in question will eventually become incompatible with the current use. Development will not begin to be exposed to sea level rise impacts until 2050, but it is important to start planning now about how best to address the risks to the houses. Managed retreat would necessitate identifying feasible locations into which houses could be moved or a plan to abandon and remove houses. Such a plan might include a Transfer of Development Rights program in which homes are encouraged in less hazardous areas. If a managed retreat strategy is not in place, existing structures may qualify for shoreline protection. Shoreline protection would likely exacerbate beach erosion, degrade public access, impair shoreline habitat, and alter visual character.
- *Wastewater Treatment Facility:* The biggest risk in this scenario is to the wastewater treatment facility. It should be determined how likely it is that the facility will be able to be protected throughout the rest of its expected lifespan under even the highest sea level rise scenarios. It may be that the wastewater treatment facility becomes an incompatible use under future conditions. If so, plans should be made to relocate at-risk portions of the facility, as feasible, or to phase out the facility.

Note that this is a simplified example used to demonstrate the process described in Step 3. Decisions about how to address various challenges presented by sea level rise will be more complex than those illustrated above and may require prioritizing the different resources based on Coastal Act requirements taking into account the goals and circumstances of the community and the various characteristics of each resource. An understanding of the exposure, sensitivity, adaptive capacity, consequences, and land use constraints for the particular resources and scenarios will need to be kept in mind as planners move into Step 4 to identify possible adaptation strategies. Updated LCP policies and ordinances should be considered to support strategy implementation over the long term.

Step 4 – Identify LCP adaptation strategies to minimize risks

Whether as part of a new LCP or as part of an amendment to update an existing LCP, coastal planners should work with the Coastal Commission and relevant stakeholders at all steps, but particularly to evaluate potential options and adaptation strategies to address the sea level rise impacts identified in Step 2 and the risks to coastal resources identified in Step 3. Planners will then develop new or revised land use designations, policies, standards, or ordinances to implement the adaptation strategies in the LCP.

An LCP as certified by the Commission should already have land use policies, standards, and ordinances to implement Coastal Act Chapter 3 policies, including policies to avoid and mitigate hazards, and to protect coastal resources. However, in older LCPs, many of these policies may not address changing conditions adequately enough to protect coastal resources over time as sea level rises. Similarly, policies to protect resources and address coastal hazards may not reflect new techniques that can be utilized to adaptively manage coastal resources in a dynamic environment. As such, the LCP should be evaluated to identify the land use designations, policies, or ordinances that need to be amended. An LCP update may need to include a variety of adaptation measures depending on the nature and location of the vulnerability. In addition, local governments may need to add new "programmatic" changes to address sea level rise, such as transfer of development credit programs, regional sediment management programs, or a land acquisition program.

In Steps 1-3, planners will have analyzed several possible sea level rise scenarios, and this analysis will have revealed valuable information about areas and specific coastal resources that are especially vulnerable to sea level rise hazards under possible scenarios. The results should show areas that are particularly resilient to future change and trigger points at which sea level hazards will become particularly relevant to certain areas. Step 3d (identifying the *Consequences* of sea level rise impacts) and Step 3e (considering the *Land use constraints*) will be particularly useful in thinking through what resources are particularly vulnerable and what the local priorities may be.

In Step 4, planners should weigh information from the previous steps, keeping in mind the hazard avoidance and resource protection policies of the Coastal Act, and begin identifying, choosing, and/or developing adaptation strategies to be included in a new or updated LCP. The options available to minimize risks from sea level rise are dependent upon the specifics of the local community, and will vary widely depending on whether the area is an urban, fully-developed waterfront, or a rural, undeveloped coastline. In undeveloped areas, the options may be clear: strictly limit new development in sea level rise hazard zones.

However, in urban areas, sea level rise can present unprecedented challenges, and the options are less clear. The Coastal Act allows for protection of certain existing structures. However, armoring can pose significant impacts to coastal resources. To minimize impacts, innovative, cutting-edge solutions will be needed, such as the use of living shorelines to protect existing infrastructure, restrictions on redevelopment of properties in hazardous areas, managed retreat, partnerships with land trust organizations to convert at risk areas to open space, or transfer of development rights programs. Strategies will need to be tailored to the specific needs of each

community based on the resources at risk, should be evaluated for resulting impacts to coastal resources, and should be developed through a public process, in close consultation with the Coastal Commission and in line with the Coastal Act.

Adaptation strategies should be selected based upon the local conditions, the results of the scenario-based analysis, and Coastal Act requirements, taking into account the particular goals of the local community. If certain adaptation strategies should be implemented when conditions reach pre-identified trigger points, those caveats should be included in the LCP. Similarly, LCP adaptation policies should be developed and implemented in such a way as to be flexible and adaptive enough that they can be changed or updated as conditions change or if sea level rise impacts are significantly different than anticipated. Additionally, many adaptation strategies should be implemented in a coordinated way through both the LCP and individual CDPs. For example, current land uses that will conflict with future conditions may be amended through updated zoning designations in an LCP. In turn, zoning designations could carry out specific policies or requirements regarding new development or redevelopment that need to be addressed in a CDP to ensure that projects are resilient over time. Planners are encouraged to work with Coastal Commission staff to ensure compliance with the Coastal Act and to coordinate and share information with other local partners including those in charge of emergency management, law enforcement, and related services, and those identified in Figure 10 as applicable and feasible.

A key issue that should be addressed in the LCP is the evaluation of strategies to minimize hazards related to existing development. Under the Coastal Act, certain improvements and repairs to existing development are exempt from CDP requirements. Non-exempt improvements and any repairs that involve the replacement of 50% or more of a structure, however, generally require a CDP and must conform to the standards of the relevant Local Coastal Program or Coastal Act.[33] Redevelopment, therefore, should minimize hazards from sea level rise. For existing structures currently sited in at-risk locations, the process of redeveloping the structure may require the structure to be moved or modified to ensure that the structure and coastal resources are not at risk due to impacts from sea level rise. As described in Guiding Principle 6, sequential renovation or replacement of small portions of existing development should be considered in total. LCPs should include policies that specify that multiple smaller renovations that amount to alteration of 50% or more of the original structure should require a Coastal Development Permit, and require that the entire structure to be brought into conformance with the standards of the Local Coastal Program or Coastal Act.[34]

[33] Section **§** 13252(b) of the Commission's regulations states that "unless destroyed by natural disaster, the replacement of 50 percent or more of a single family residence, seawall, revetment, bluff retaining wall, breakwater, groin or any other structure is not repair and maintenance under Coastal Act Section 30610(d) but instead constitutes a replacement structure requiring a Coastal Development Permit."

[34] In addition, for existing structures located between the first public road and the sea or within 300 feet of the inland extent of a beach, improvements that increase the height or internal floor area by more than 10% normally require a CDP. (Cal. Code Regs., tit. 14, §§13250(b)(4), 13253(b)(4).) Depending upon the location of the structure, smaller improvements may also require a CDP. (Cal. Code Regs., tit. 14, §§ 13250(b), 13253(b).)

General Adaptation Strategies:

Chapter 7 describes a number of adaptation policies and strategies and is organized by resource type to allow users to easily identify the types of policies that may be relevant to local resource vulnerabilities. However, there are a number of adaption strategies or related actions that apply to a variety of resources or that may be generally useful when adopting or updating an LCP. Some of these adaptation strategies and actions are broadly described below.

- **Update resource inventory and maps**: An important first step for addressing sea level rise hazards and vulnerabilities in a new or updated LCP will be to compile a set of maps that clearly show the current locations of the range of coastal resources present in an LCP jurisdiction (*e.g.*, beaches and public accessways; agricultural land, wetlands, ESHA, and other coastal habitats; energy, wastewater, transportation, and other critical infrastructure; and archaeological and paleontological resources), as well as existing land use designations, and hazard areas. It may also be helpful to map possible future conditions based on the analysis done in Steps 1-3. Doing so will help planners begin to identify possible land use and zoning changes and other adaptation strategies that will be necessary to meet hazard avoidance and resource protection goals.
- **Update land use designations and zoning ordinances**: One of the most common methods of regulating land use is through zoning designations and ordinances, and updating these policies is one of the most fundamental ways of responding to sea level rise impacts. Planners may address particular vulnerabilities and local priorities by updating land use designations and zoning ordinances to protect specific areas and/or resources. For example, areas that are particularly vulnerable to sea level rise impacts can be designated as hazard zones and specific regulations can be used to limit new development and/or to encourage removal of existing development in such zones. Similarly, open areas can be designated as conservation zones in order to protect and provide upland areas for wetland and habitat migration or for additional agricultural land.
- **Update siting and design standards**: Updated siting and design standards may go hand in hand with updated land use designations and zoning ordinances in that specific standards may be required for development or projects in certain zones. For example, development in hazard zones may require additional setbacks, limits for first floor habitable space, innovative stormwater management systems, special flood protection measures, mitigation measures for unavoidable impacts, relocation and removal triggers and methodologies, and so on.
- **Establish methods to monitor local changes from sea level rise**: Add policies that establish actions to conduct long-term sea level rise monitoring and research on areas of key uncertainties, areas sensitive to small changes in sea level rise, or areas with high sea level rise risk.
- **Research and data collection**: Support research to address key data gaps and better utilize existing information. Local governments may find it useful to collaborate with local, regional, and state partners to pursue new research to better understand the factors controlling sea level rise, baseline shoreline conditions, ecosystem responses to sea level rise, potential impacts and vulnerabilities, and the efficacy of adaptation tools. Related efforts may include monitoring programs designed to track trends in local shoreline

change, flooding extent and frequency, or water quality. Monitoring of the results of various adaptation strategies and protective structures could be included as part of a Coastal Development Permit for projects in hazard zones.

- **Outreach and education**: Education and outreach efforts involve formal instruction and provision of information to stakeholders, and can help generate support for planning and action implementation. It is important to coordinate with partners and include all relevant stakeholders in these processes, particularly those that are typically isolated, such as low-income or underserved communities. For many people, sea level rise is a new issue. Information on sea level rise science and potential consequences may motivate stakeholders to take an active role in updating the LCP for sea level rise issues, or in the vulnerability and risk assessment efforts. Additionally, education efforts regarding the risks of sea level rise as well as possible adaptation strategies may encourage people to take proactive steps to retrofit their homes to be more resilient or to choose to build in less hazardous areas.

As stated above, a more extensive and detailed list of possible adaptation strategies can be found in Chapter 7. The list should neither be considered a checklist from which all options need to be added to an LCP, nor is it an exhaustive list of all possible adaptation strategies. Sea level rise adaptation is still an evolving field and decision makers will need to be innovative and flexible to respond to changing conditions, new science, and new adaptation opportunities. The important point is to analyze current and future risks from sea level rise, determine local priorities and goals for protection of coastal resources and development, and identify what land use designations, zoning ordinances, and other adaptation strategies can be used to meet those goals within the context of the Coastal Act.

***Expected outcomes from Step 4**: Identified sections of the LCP that need to be updated, a list of adaptation measures applicable to the LCP, and new policies and ordinances to implement the adaptation measures.*

Step 5 – Draft updated or new LCP for certification with the Coastal Commission

Once potential adaptation strategies have been identified, LCP policies that address sea level rise should be incorporated into a new LCP or LCP amendment. For jurisdictions with a certified LCP, adaptation measures will be implemented through development of amendments to the certified LCPs. For jurisdictions that currently do not have a certified LCP, the sea level rise policies will be part of the development of a new LCP. In areas without a certified LCP, the Coastal Commission generally retains permitting authority, and the standard of review for development is generally Chapter 3 of the California Coastal Act.

As noted in Step 4, sea level rise has the potential to affect many types of coastal resources in an LCP planning area/segment, and it is likely that policies throughout the LCP will need to be revised or developed to address impacts from sea level rise. Two major types of updates to the LCP will likely be needed to address sea level rise:

1. New or revised policies/ordinances that apply to all development in the planning area. For example, policies such as "All new development shall be sited and designed to minimize risks from sea level rise over the life of the structure."
2. Updated land use and zoning designations, as well as programs to facilitate adaptive community responses, to reduce risks to specific coastal resources. For example, the LCP could modify the zoning of undeveloped land located upland of wetlands from residential to open space in order to provide the opportunity for wetlands to migrate inland, and protect wetlands for the future.

Local government staff should work closely with Coastal Commission staff and relevant stakeholders, including ensuring there is opportunity for public input, to develop the new LCP or LCP amendments. Once the updates and plans are complete, local governments will submit to the Commission for certification. The Commission may either certify or deny the LCP or LCP amendment as submitted, or it may suggest modifications. If the Commission adopts suggested modifications, the local government may adopt the modifications for certification or refuse the modifications and resubmit a revised LCP for additional Commission review. For more information on updating LCPs, see http://www.coastal.ca.gov/la/lcp.html.

Expected outcomes from Step 5*: Certified/updated LCP with policies and land use designations that address sea level rise and related hazards and ensure protection of coastal resources to the maximum extent feasible.*

Step 6 – Implement LCP and monitor and revise as needed

Upon certification of the updated LCP, sea level rise adaptation strategies will be implemented through the certified implementing ordinances and related processes and actions (*e.g.*, local review of CDPs, proactive action plans). Additionally, an important component of successful adaptation is to secure funds for implementation, regularly monitor progress and results, and update any policies and approaches as needed. Sea level rise projections should be re-evaluated and updated as necessary.

- **Secure resources for implementation:** There are a number of different sources of funds available to help local governments implement adaptation strategies. For example, the Coastal Commission, the Ocean Protection Council, and the Coastal Conservancy have grant programs designed to support local adaptation efforts (see Chapter 1 for additional details on each of these programs).

  As described previously there may also be overlap between LCP planning and Local Hazard Mitigation planning. FEMA's Hazard Mitigation Assistance (HMA) grant programs provide significant opportunities to reduce or eliminate potential losses to State, Indian Tribal government, and local assets through hazard mitigation planning and project grant funding. Currently, there are three programs: the Hazard Mitigation Grant Program (HMGP); Pre-Disaster Mitigation (PDM); and Flood Mitigation Assistance

(FMA)[35]. Cal OES administers the HMA and FMA programs. More information can be found at http://hazardmitigation.calema.ca.gov/grants or the FEMA HMA Web site at https://www.fema.gov/hazard-mitigation-assistance.

A list compiled by Cal OES of additional funding options for hazard mitigation can be found in Appendix E. The Commission recognizes that funding opportunities are constantly evolving, that demand for funding is increasing, and that there is a significant need for the development of additional funding opportunities.

- **Identify key resources to monitor:** Certain species can be indicators of whether sea level rise is affecting an ecosystem. For instance, the presence of certain plant species can indicate the salinity of soils. Also, monitoring plans should reflect the outcome of the scenario-based analysis of sea level rise. Some adaptation measures might be earmarked for implementation when a certain amount of sea level rise (or a particular sea level rise impact) occurs. Monitoring programs should ensure that these triggers are recognized and responded to at the appropriate time.

- **Periodically Update LCPs:** Local governments should try to review their vulnerability and risk assessments on a regular basis as significant new scientific information becomes available and propose amendments as appropriate. Given the evolving nature of sea level rise science, policies may need to be updated as major scientific advancements are made, changing what is considered the best available science. Modify the current and future hazard areas on a five to ten year basis or as necessary to allow for the incorporation of new sea level rise science, monitoring results, and information on coastal conditions. Regular evaluation of LCPs is important to make sure policies and adaptation strategies are effective in reducing impacts from sea level rise.

Expected outcomes from Step 6*: Plan to monitor the LCP planning area for sea level rise and other impacts and for effectiveness of various adaptation strategies that are implemented; plan to revise the LCP when conditions change or science is updated.*

This six-step process discussed in this chapter is illustrated in the flowchart below (Figure 12). Notice that the process is circular. Because sea level rise science will be refined and updated in the future, planners should periodically repeat this six-step process to update and improve their LCPs.

For additional resources and examples of ways to incorporate sea level rise into the LCP, see Appendix C.

[35] Each HMA program was authorized by separate legislative action, and as such, each program differs slightly in scope and intent.

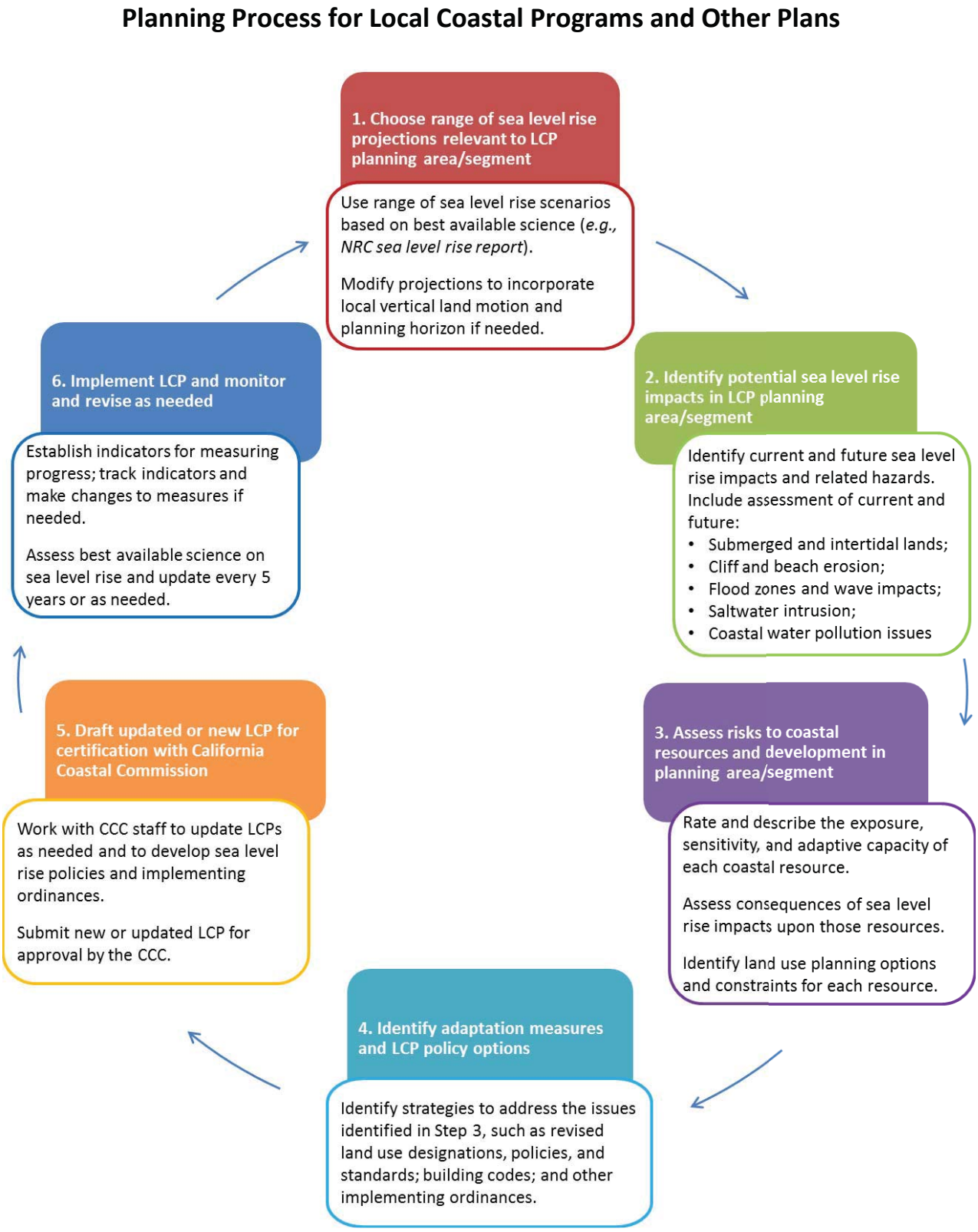
Planning Process for Local Coastal Programs and Other Plans
1. Choose range of sea level rise projections relevant to LCP planning area/segment
Use range of sea level rise scenarios based on best available science (e.g., NRC sea level rise report).
Modify projections to incorporate local vertical land motion and planning horizon if needed.
2. Identify potential sea level rise impacts in LCP planning area/segment
Identify current and future sea level rise impacts and related hazards. Include assessment of current and future:
• Submerged and intertidal lands;
• Cliff and beach erosion;
• Flood zones and wave impacts;
• Saltwater intrusion;
• Coastal water pollution issues
3. Assess risks to coastal resources and development in planning area/segment
Rate and describe the exposure, sensitivity, and adaptive capacity of each coastal resource.
Assess consequences of sea level rise impacts upon those resources.
Identify land use planning options and constraints for each resource.
4. Identify adaptation measures and LCP policy options
Identify strategies to address the issues identified in Step 3, such as revised land use designations, policies, and standards; building codes; and other implementing ordinances.
5. Draft updated or new LCP for certification with California Coastal Commission
Work with CCC staff to update LCPs as needed and to develop sea level rise policies and implementing ordinances.
Submit new or updated LCP for approval by the CCC.
6. Implement LCP and monitor and revise as needed
Establish indicators for measuring progress; track indicators and make changes to measures if needed.
Assess best available science on sea level rise and update every 5 years or as needed.

Figure 12. Flowchart for addressing sea level rise in Local Coastal Programs and other plans

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Chapter 6

Addressing Sea Level Rise in Coastal Development Permits

Development in the coastal zone generally requires a Coastal Development Permit (CDP).[36] In areas of retained jurisdiction and areas without a certified Local Coastal Program (LCP), the Commission is generally responsible for reviewing the consistency of CDP applications with the policies of Chapter 3 of the Coastal Act (Public Resources Code Sections 30200-30265.5).[37] In areas with a certified LCP, the local government is responsible for reviewing the compliance of CDP applications with the requirements of the certified LCP and, where applicable, the public access and recreation policies of the Coastal Act. Certain local government actions on CDP applications are appealable to the Commission. On appeal, the Commission also applies the policies of the certified LCP and applicable public access and recreation policies of the Coastal Act.[38] The Commission and local governments may require changes to the project or other mitigation measures in order to assure compliance with Coastal Act policies or LCP requirements by both minimizing risks to the development from coastal hazards and avoiding impacts to coastal resources.

The Coastal Act, the LCP, and the CDP Application cover the broad range of information and analyses that must be addressed in a CDP application. This CDP guidance focuses only on sea level rise and those conditions or circumstances that might change as a result of changing sea level. It does not address other Coastal Act or LCP requirements.

Adopting or updating LCPs as recommended in this Guidance should facilitate subsequent review of CDPs. LCPs can identify areas where close review of sea level rise concerns is necessary and where it is not. If kept up to date, they can also provide information for evaluation at the permit stage and specify appropriate mitigation measures for CDPs to incorporate.

Sea level rise will be important for some, but not all, of the projects reviewed through the CDP process. Locations currently subject to inundation, flooding, wave impacts, erosion, or saltwater intrusion will be exposed to increased risks from these coastal hazards with rising sea level and will require review for sea level rise effects. Locations close to or hydraulically connected to these at-risk locations, will themselves be at risk as sea level rises and increases the inland extent

[36] Coastal Act Section 30106 defines "Development" to be, "on land, in or under water, the placement or erection of any solid material or structure; discharge or disposal of any dredged material or of any gaseous, liquid, solid, or thermal waste; grading, removing, dredging, mining, or extraction of any materials; change in the density or intensity of use of land, including, but not limited to, subdivision pursuant to the Subdivision Map Act (commencing with Section 66410 of the Government Code), and any other division of land, including lot splits, except where the land division is brought about in connection with the purchase of such land by a public agency for public recreational use; change in the intensity of use of water, or of access thereto; construction, reconstruction, demolition, or alteration of the size of any structure, including any facility of any private, public, or municipal utility; and the removal or harvesting of major vegetation other than for agricultural purposes, kelp harvesting, and timber operations which are in accordance with a timber harvesting plan submitted pursuant to the provisions of the Z'berg-Nejedly Forest Practice Act of 1973 (commencing with Section 4511)."

[37] The Commission retains CDP jurisdiction below mean high tide and on public trust lands.

[38] Local governments may assume permitting authority even without a fully certified LCP (*see* Public Resources Code, §§ 30600(b), 30600.5), but only the City of Los Angeles has done so. Any action on a CDP application by a local government without a fully certified LCP may be appealed to the Commission. (Public Resources Code, § 30602.)

of these hazards. The following box provides some of the general situations for which sea level rise will need to be included in the project analysis.

General Situations when sea level rise should be considered in the project analysis include when the project or planning site is:

- Currently in or adjacent to an identified floodplain
- Currently or has been exposed to flooding or erosion from waves or tides
- Currently in a location protected by constructed dikes, levees, bulkheads, or other flood-control or protective structures
- On or close to a beach, estuary, lagoon, or wetland
- On a coastal bluff with historic evidence of erosion
- Reliant upon shallow wells for water supply

Many of the projects reviewed through the CDP application process already examine sea level rise as part of the hazards analysis. Such examination will need to continue, and these guidelines offer direction and support for a thorough examination of sea level rise and its associated impacts based on current climate science, coastal responses to changing sea level, and consequences of future changes.

To comply with Coastal Act Section 30253 or the equivalent LCP section, projects will need to be planned, located, designed, and engineered for the changing water levels and associated impacts that might occur over the life of the development. In addition, project planning should anticipate the migration and natural adaptation of coastal resources (beaches, access, wetlands, *etc.*) due to future sea level rise conditions in order to avoid future impacts to those resources from the new development. As LCPs are updated to reflect changing conditions and to implement sea level rise adaptation strategies, it will be important that CDPs are also conditioned and approved in ways that similarly emphasize an adaptive approach to addressing sea level rise hazards. Such coordination between LCP and CDP adaptation policies and strategies will help ensure that coastal development and resources are resilient over time.

Steps for Addressing Sea Level Rise in Coastal Development Permits

The steps presented in Figure 13 and described in more detail below, provide general guidance for addressing sea level rise in the project design and permitting process for those projects where sea level rise may be contribute to or exacerbate hazards or impact coastal resources.

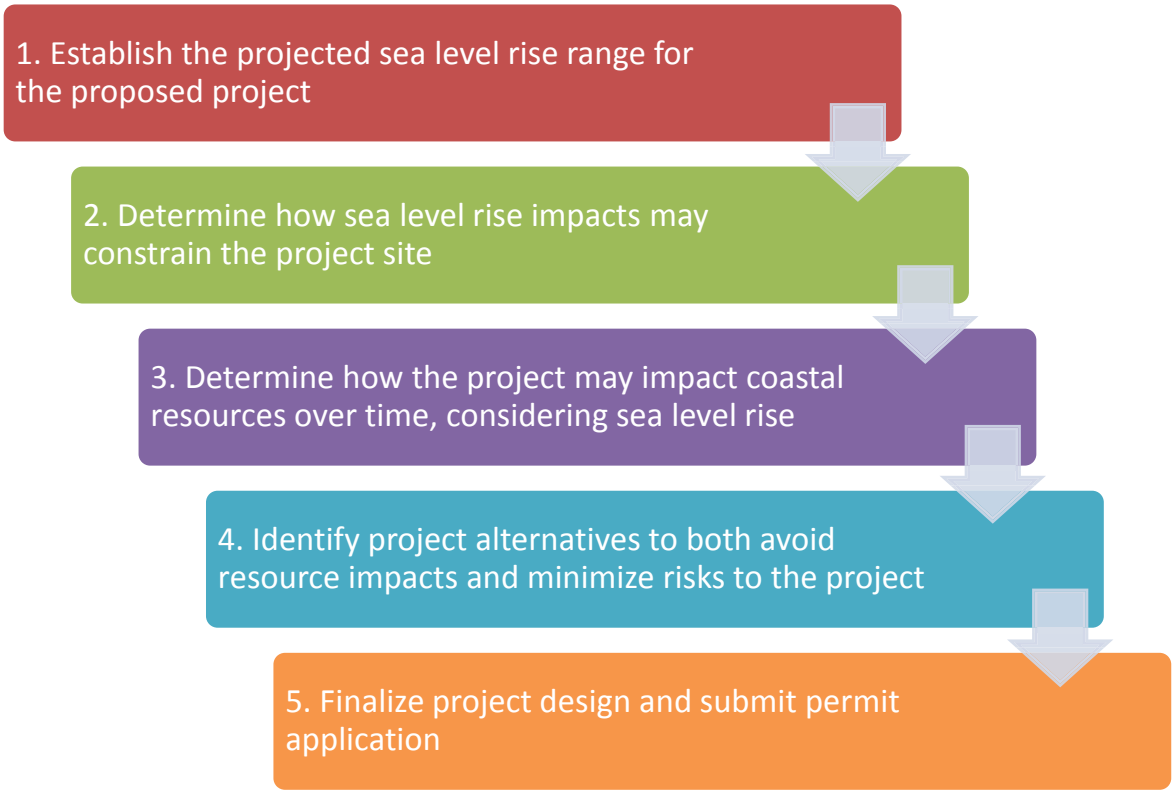
1. Establish the projected sea level rise range for the proposed project
2. Determine how sea level rise impacts may constrain the project site
3. Determine how the project may impact coastal resources over time, considering sea level rise
4. Identify project alternatives to both avoid resource impacts and minimize risks to the project
5. Finalize project design and submit permit application

Figure 13. Process for addressing sea level rise in Coastal Development Permits

The goal of these steps is to ensure that projects are designed and built in a way that minimizes risks to the development and avoids impacts to coastal resources in light of current conditions and the changes that may arise over the life of the project. Many project sites and proposed projects may raise issues not specifically contemplated by the following guidance steps or the permit filing checklist at the end of this section. It remains the responsibility of the project applicant to adequately address these situations so that consistency with the Coastal Act and/or LCP may be fully evaluated. There are many ways to evaluate and minimize the risks associated with sea level rise, and the Commission understands that different types of analyses and actions will be appropriate depending on the type of project or planning effort.

Throughout the CDP analysis, applicants are advised to contact planning staff (either at the Commission or the local government, whichever is appropriate) to discuss the proposed project, project site, and possible resource or hazard concerns. The extent and frequency of staff coordination may vary with the scale of the proposed project and the constraints of the proposed project site. Larger projects and more constrained sites will likely necessitate greater coordination with local government and Commission staff.

Use scenario-based analysis

This process recommends using various sea level rise scenarios for the analysis of possible resource changes and site risks associated with sea level rise. Given the uncertainty about the magnitude and timing of future sea level rise, a scenario-based analysis will examine the consequences of a range of situations rather than basing project planning and design upon one sea level rise projection.

One approach for scenario-based analysis is to start with the highest possible sea level rise. If a developable area can be identified that has no long-term resource impacts, and is at no or low-risk from inundation, flooding, and erosion, then there may be no benefit to undertaking additional analysis for sea level rise and the project can continue with the rest of the analyses that are part of the Coastal Act or LCP (such as impacts to coastal habitats, public access, and scenic and visual qualities, and other issues unrelated to sea level rise).

If the site is constrained under a high sea level rise scenario, analysis of other, lower sea level rise amounts can help determine thresholds for varying impacts to coastal resources and types and extent of site constraints that need to be considered during project planning. The analysis of lower and intermediate sea level rise projections are used to better understand the timing and probability of the constraints. For further description of scenario-based analysis, see Chapter 3 of this Guidance.

Step 1 – Establish the projected sea level rise range for the proposed project

A projected sea level rise range should be obtained from the best available science, such as the 2012 National Research Council (NRC) report or an equivalent resource. These projections should cover the expected life of the proposed project, as the ultimate objective will be to assure that the project is safe from coastal hazards, without the need for shoreline protection or other detrimental hazard mitigation measures, as long as it exists.

- **Define Expected Project Life**: The expected project life will help determine the amount of sea level rise to which the project site could be exposed while the development is in place. Importantly, the point of this step is not to specify exactly how long a project will exist (and be permitted for), but rather to identify a project life time frame that is typical for the type of development in question so that the hazard analyses performed in subsequent steps will adequately consider the impacts that may occur over the entire life of the development.

  Some LCPs include a specified design life for new development. If no specified time frame is provided, a more general range may be chosen based on the type of development. For example, temporary structures, ancillary development, amenity structures, or moveable or expendable construction may identify a relatively short expected life such as 25 years or less. Residential or commercial structures will likely be around for some time, so a time frame of 75 to 100 may be appropriate. A longer time frame of 100 years or more should be considered for critical infrastructure like bridges or industrial facilities. Resource protection or enhancement projects such as coastal habitat

conservation or restoration projects should also consider longer time frames of 100 years or more, as these types of projects are typically meant to last in perpetuity.[39]

- **Determine Sea Level Rise Range:** Using the typical project life identified above, the project analysis should identify a range of sea level rise projections based on the best available science that may occur over the life of the project. At present, the 2012 NRC report is considered to be the best available science (Table 6)[40], though an equivalent resource may be used provided that it is peer-reviewed, widely accepted within the scientific community, and locally relevant. Appendix B provides information on how to determine sea level rise amounts for years that are not included in the NRC report and, if needed, how to modify the NRC sea level rise projections to account for local vertical land motion. At a minimum, one high sea level rise projection for the proposed life of the project should be used for project analysis and evaluation. If constraints are identified with the high sea level rise scenario, a low sea level rise scenario and/or one or more intermediate rise scenarios should also be used. For critical infrastructure, development with a very long project life, or for projects with the potential to have severe impacts to Coastal Act resources, the analysis may also consider higher scenarios (such as a 2-m (6.6-ft) scenario[41]). These values should each be carried forward through the rest of the steps in this chapter.

Table 6. Sea Level Rise Projections for California (NRC 2012)

TIME PERIOD*	NORTH OF CAPE MENDOCINO	SOUTH OF CAPE MENDOCINO	
by 2030	-2 – 9 in (-4 – +23 cm)	2 – 12 in (4 – 30 cm)	
by 2050	-1 – 19 in (-3 – + 48 cm)	5 – 24 in (12 – 61 cm)	
by 2100	4 – 56 in (10 – 143 cm)	17 – 66 in (42 – 167 cm)	

*with Year 2000 as a baseline

[39] Determining an anticipated life for restoration activities or other related projects is somewhat more complex than for typical development projects because these activities are typically meant to exist in perpetuity. As such, assessing sea level rise impacts may necessitate analyzing multiple different time frames, including the present, near future, and very long term depending on the overall goals of the project. For restoration projects that are implemented as mitigation for development projects, an expected project life that is at least as long as the expected life of the corresponding development project should be considered.

[40] The NRC Committee divided the Pacific coast for California, Oregon and Washington into two regions, north and south of Cape Mendocino, due to differences in tectonics that occur at this point. North of Cape Mendocino, land is rising as ocean plates descend below the North American plate at the Cascadia Subduction Zone. South of Cape Mendocino, the coast is sinking (NRC 2012, p. 3). Humboldt Bay has not experienced the regional uplift that characterizes most of the coast north of Cape Mendocino, and instead has shown the highest subsidence recorded for the California coast. As a result, the projections for north of Cape Mendocino may not be appropriate for use in or near Humboldt Bay and the Eel River Estuary.

[41] The Global Sea Level Rise Scenarios for the United States National Climate Assessment 2012 established 6.6 ft (2 m) as the highest global sea level rise scenario for 2100.

Note that for project locations in the vicinity of Humboldt Bay and the Eel River estuary, the regional NRC sea level rise projections will need to be modified to adjust for localized vertical land motion.[42] Adjustments for vertical land motion are not necessary for other locations, though they may be done if desired and if locally relevant data are available.[43] If sea level rise projections are modified for areas other than the Humboldt Bay region, at least one scenario for the analysis of impacts should use the high value from the unmodified NRC projections in order to assess a worst case scenario possibility.

***Expected outcomes from Step 1**: A proposed or expected project life and corresponding range of sea level projections—including the high, the low, and one or more intermediate sea level rise projections—that will be used in the following analytic steps.*

Step 2 – Determine how physical impacts from sea level rise may constrain the project site

The Coastal Act requires that development minimize risks from coastal hazards. Sea level rise can both present new hazards and exacerbate hazards that are typically analyzed in CDP applications. In this step, project applicants determine the types and extent of sea level rise impacts that may occur now and into the future.

As described in Chapter 3 of the Guidance, impacts associated with sea level rise generally include erosion, inundation, flooding, wave impacts, and saltwater intrusion. An assessment of these impacts is often required as part of a routine hazards assessment or the safety element of the LCP. Therefore, information in the local LCP can provide an initial determination of potential hazards for the project in question, if available. However, proposed development will often need a second, site-specific analysis of hazards to augment the more general LCP information.

Analyze relevant sea level rise impacts for each sea level rise scenario.

A CDP application for new development in a hazardous area should include reports analyzing the anticipated impacts to a project site associated with each sea level rise scenario identified in Step 1. Generally, the analyses pertinent to sea level rise include geologic stability, erosion, flooding/inundation, wave runup, and wave impacts, and these analyses are described in detail below. Depending on the site, however, different analyses may be required. Applicants should work with planning staff (Coastal Commission or local government staff) to perform a pre-application submittal consultation to determine what analyses are required for their particular

[42] Please see Appendix B and *Humboldt Bay: Sea Level Rise Hydrodynamic Modeling, and Inundation Vulnerability Mapping* (Northern Hydrology and Engineering 2015) for additional information on VLM and sea level rise projections for the Humboldt Bay region.

[43] A three-member subcommittee of the OPC Science Advisory Team (OPC-SAT) advised using the NRC projections, without modification, for all California locations except between Humboldt Bay and Crescent City. The OPC-SAT subcommittee stated, "We do not believe that there is enough certainty in the sea level rise projections nor is there a strong scientific rationale for specifying specific sea level rise values at individual locations along California's coastline." (OPC 2013, p. 10)

project. Analysis of those hazards that will not be altered by sea level rise (such as the location of faults, fire zones, *etc.*) should be undertaken at the same time as the assessment of sea level rise affected hazards so a complete understanding of hazard constraints can be used for identification of safe or low-hazard building areas. After the submission of the CDP application, any additional analyses that are required will be listed in an application filing status review letter.

The professionals who are responsible for technical studies of geologic stability, erosion, flooding/inundation, wave runup, and wave impacts should be familiar with the methodologies for examining the respective impacts. However, the methodologies do not always adequately examine potential impacts under rising sea level conditions, as established by best available science. Appendix B goes through the various steps for incorporating the best available science on sea level rise into the more routine analyses, which are summarized below. The analyses should be undertaken for each of the sea level rise scenarios identified in Step 1.

- **Geologic Stability:** The CDP should analyze site-specific stability and structural integrity without reliance upon existing or new protective devices (including cliff-retaining structures, seawalls, revetments, groins, buried retaining walls, and caisson foundations) that would substantially alter natural landforms along bluffs and cliffs. Geologic stability can include, among others, concerns such as landslides, slope failure, liquefiable soils, and seismic activity. In most situations, the analyses of these concerns will be combined with the erosion analysis (below) to fully establish the safe developable area.
- **Erosion:** Both bluff erosion and long-term shoreline change will increase as the time period increases. Thus, some estimate of project life is needed to determine expected bluff and shoreline change, and to fully assess the viability of a proposed site for long-term development. The CDP application should include an erosion analysis that establishes the extent of erosion that could occur from current processes, as well as future erosion hazards associated with the identified sea level rise scenarios over the life of the project. If possible, these erosion conditions should be shown on a site map, and the erosion zone, combined with the geologic stability concerns, can be used to help establish locations on the parcel or parcels that can be developed without reliance upon existing or new protective devices (including cliff-retaining structures, seawalls, revetments, groins, buried retaining walls, and caissons) that would substantially alter natural landforms along bluffs and cliffs.
- **Flooding and Inundation:** The CDP application should identify the current tidal datum and include analysis of the extent of flooding or inundation that potentially could occur from the identified sea level rise scenarios, and under a range of conditions that could include high tide, storm surge, water elevation due to El Niños, Pacific Decadal Oscillations, a 100-year storm event, and the combination of long-term erosion and seasonal beach erosion. If possible, this information and resulting flood zones should be shown on a site map.
    - **Flood Elevation Certificate**: If a site is within a FEMA-mapped 100-year flood zone, building regulations, in implementing the federal flood protection program, require new residences to have a finished floor elevation above Base Flood

Elevation (BFE; generally 1 ft).[44] The CDP application should include a flood elevation certificate prepared by a registered land surveyor, engineer, or architect, demonstrating that the finished floor foundation of the new structure will comply with the minimum FEMA guidelines and building standards. However, at this time, the Flood Certificate does not address sea level rise related flooding. In addition, designing to meet FEMA requirements may be in conflict with other resource constraints, such as protection of visual resources, community character, and public access and recreation. Thus, in general, a certificate is not adequate to address Coastal Act and LCP standards for demonstrating that future flood risk or other impacts to coastal resources have been minimized.

- **Wave Runup and Wave Impacts:** Building upon the analysis for flooding, the CDP application should include analysis of the wave runup and impacts that potentially could occur over the anticipated life of the project from a 100-year storm event, combined with the identified sea level rise scenarios, and under a range of conditions that could include high tide, storm surge, water elevation due to El Niño events, Pacific Decadal Oscillations, and the combination of long-term erosion and seasonal beach erosion. If possible, this information and resulting wave runup zones should be shown on a site map or site profile.
- **Other Impacts**: Any additional sea level rise related impacts that could be expected to occur over the life of the project, such as saltwater intrusion should be evaluated. This may be especially significant for areas with a high groundwater table such as wetlands or coastal resources that might rely upon groundwater, such as agricultural uses.

Expected outcomes from Step 2*: Detailed information about the sea level rise related impacts that can occur on the site and changes that will occur over time under various sea level rise scenarios. High risk and low risk areas of the site should be identified. The scenario-based analyses should also provide information on the potential effects of sea level rise, such as coastal erosion, that could occur over the proposed development life, without relying upon existing or new protective devices.*

[44] FEMA's proposed "Revised Guidelines for Implementing Executive Order 11988, Floodplain Management" (released for public review and comment on January 30, 2015) will modify the Federal Flood Risk Management Standard, in compliance with EO 13960, to address the need for federal agencies to include climate change considerations in floodplain management. It recommends that the elevation and flood hazard area be established by (i) using climate-informed science, (ii) adding 2 feet (for non-critical actions) or 3 feet (for critical actions) of freeboard to the Base Flood Elevation, or (iii) including the area subject to the 0.2% annual chance of flood. These Revised Guidelines could lead to future changes in the elevation required for Flood Elevation Certificates for new development.

Step 3 – Determine how the project may impact coastal resources, considering the influence of sea level rise upon the landscape over time

The Coastal Act requires that development avoid impacts to coastal resources. Sea level rise will likely cause some coastal resources to change over time, as described in Chapters 3 and 4. Therefore, in this step, applicants should analyze how sea level rise will affect coastal resources now and in the future so that alternatives can be developed in Step 4 to minimize the project's impacts to coastal resources throughout its lifetime.

This section discusses only those resources that might change due to rising sea level or possible responses to rising sea levels. As in Step 2, each sea level rise scenario (high, low, and intermediate values) should be carried through this step. A complete CDP application will need to assess possible impacts to all coastal resources – including public access and recreation, water quality, natural resources (such as ESHA and wetlands), agricultural resources, natural landforms, scenic resources, and archaeological and paleontological resources. Analysis of those resources that will not be affected by sea level rise should be undertaken at the same time as the assessment of the sea level rise affected resources so a complete map of resource constraints can be used for identification of a resource-protective building area.

3.1 Analyze coastal resource impacts and hazard risks for each sea level rise scenario

Analysis of resource impacts will require information about the type and location of the resources on or in proximity to the proposed project site and the way in which the proposed project will affect such resources initially and over time. The following discussion of each resource will help identify the key impacts to each that might result from either sea level rise or the proposed development. If coastal resources will be affected by sea level rise, such as changes to the area and extent of a wetland or riparian buffer, these changes must be considered in the analysis. Much of the following discussion recommends analysis of impacts from current and future inundation, flooding, erosion, and from the ways in which the project proposes to address such impacts. Appendix B provides guidance on how to undertake this analysis and includes lists of suggested resources that can provide data, tools, or other resources to help with these analyses. This analysis should be repeated for each sea level rise scenario identified in Step 1. Also, it may be important for local planners to coordinate and share information with other local partners – including those in charge of emergency management, law enforcement, and related services – in order to identify risks and vulnerabilities. Information on the following coastal resources is included. To skip to a section, click on the links below:

- New Development (addressed in Step 2, above)
- Public Access and Recreation
- Coastal Habitats
- Natural Landforms
- Agricultural Resources
- Water Quality and Groundwater
- Scenic Resources

Public Access and Recreation: Public access and recreation resources include lateral and vertical public accessways, public access easements, beaches, recreation areas, public trust lands,[45] and trails, including the California Coastal Trail. These areas may become hazardous or unusable during the project life due to sea level rise and/or due to the proposed project. Approaches to identify potential risks to public access and recreation include:

- Identify all public access locations on or near the proposed project site and, if possible, map these resources in relation to the location of the proposed project. The analysis should also identify existing public trust areas in relation to the proposed project
- Determine whether any access locations or public trust lands will be altered or impacted by sea level rise and/or the proposed project for the identified sea level rise scenarios. Such impacts could result from flooding, inundation, or shoreline erosion, or from proposed project elements. At a minimum, establish the extent of likely and/or possible changes to public access and recreation and to public trust lands.
- If any access locations will be altered by sea level rise and/or the proposed project, map or otherwise identify the potential changes to the location of these access resources for the identified sea level rise scenarios.
- Identify whether there are locations on the proposed project site that can support development without encroachment onto the existing or future locations of these access locations, and without impacts otherwise to public access and recreation. Overlay with development constraints (fault zones, landslides, steep slopes, property line setbacks, *etc.*) and with other coastal resource constraints.

Coastal Habitats (ESHA, wetlands, *etc.*): Coastal habitats, especially those that have a connection to water, such as beaches, intertidal areas, and wetlands, can be highly sensitive to changes in sea level. Ways to identify potential resource impacts associated with the project include:

- Identify all coastal habitats and species of special biological or economic significance on or near the proposed project site and, if possible, map these resources in relation to the location of the proposed project.
- Determine whether any coastal habitats will be altered or affected by sea level rise and/or the proposed project over the proposed life of the project. Such impacts could result from flooding, inundation, shoreline erosion, or changes to surface or groundwater conditions (see discussion below on water quality). At a minimum, use the identified sea level rise scenarios to establish the extent of likely and/or possible changes to coastal habitats.
- If any coastal habitats will be altered by sea level rise and/or the proposed project, map or otherwise identify potential changes to the location of these coastal resources for the identified sea level rise scenarios.
- Identify locations of the proposed project site that can support development without encroachment onto the existing or future locations of these coastal habitats, and without

[45] The State Lands Commission has oversight of all public trust lands and many local governments are trustees of granted tidelands. The State Lands Commission or other appropriate trustee should be contacted if there is any possibility that public trust lands might be involved in the proposed project. As a general guide, public trust lands include tide and submerged lands as well as artificially filled tide and submerged lands.

other impacts to coastal habitats. Overlay with development constraints (fault zones, landslides, steep slopes, property line setbacks, *etc.*) and with other coastal resource constraints.

Natural Landforms: Natural landforms can include coastal caves, rock formations, bluffs, terraces, ridges, and cliffs. Steps to identify natural landforms at risk include:

- Identify all natural landforms on or near the proposed project site and, if possible map these resources in relation to the location of the proposed project.
- Determine whether any natural landforms will be altered or impacted by sea level rise and/or the proposed project for the identified sea level rise scenarios. Such impacts could result from flooding, inundation or shoreline erosion. At a minimum, use the identified sea level rise scenarios to establish the zone of likely and/or possible changes to natural landforms.
- If any natural landforms will be altered by sea level rise and/or the proposed project, map or otherwise identify the likely changes to location of these coastal resources for the identified sea level rise scenarios.
- Identify locations of the proposed project site that can support development without encroachment onto the existing or future locations of these natural landforms and without other impacts to such landforms. Bluffs and cliffs can often require additional analysis for slope stability to determine the setback from the eroded bluff face that can safely support development. Overlay with development constraints (fault zones, landslides, steep slopes, property line setbacks, *etc.*) and with other coastal resource constraints.

Agricultural Resources: Agricultural resources may be affected by sea level rise through changes to surface drainage and the groundwater table. Other changes can result from flooding, inundation or saltwater intrusion. If agricultural lands are protected by levees or dikes, they can be affected by changes to the stability or effectiveness of these structures. Steps to identify risks to agricultural resources include:

- Identify whether the proposed project site is used for or zoned for agricultural uses, contains agricultural soils, or is in the vicinity of or upstream of lands in agricultural use.
- Identify surface water drainage patterns across the site or from the site to the agricultural use site.
- If any drainage patterns are closely linked to and potentially influenced by the elevation of sea level, examine changes in drainage patterns with rising sea level on the proposed site or the agricultural use site.

Water Quality and Groundwater: Sea level rise may cause drainages with a low elevation discharge to have water back-ups. It may also cause a rise in the groundwater table. Both of these changes could alter on-site drainage and limit future drainage options. If the proposed site must support an on-site wastewater treatment system, or if drainage and on-site water retention will be a concern, consider the following, as appropriate:

- Identify surface water drainage patterns across the site.

- Examine changes with rising sea level of any drainage patterns that are closely linked to and likely influenced by the elevation of sea level. At a minimum, use the identified sea level rise scenarios to establish the zone of likely changes to drainage patterns.
- Identify the elevation of the groundwater table. Since groundwater can fluctuate during periods of rain and drought, attempt to identify the groundwater zone.
- Estimate the likely future elevation of the groundwater zone, due to sea level rise. At a minimum, use the identified sea level rise scenarios to establish the zone of likely changes to groundwater.
- Evaluate whether changes in groundwater will alter the proposed site conditions.

Scenic Resources: Visual and scenic resources include views to and along the ocean and scenic coastal areas. Development modifications to minimize risks from sea level rise could have negative consequences for scenic resources, including creating a structure that is out of character with the surrounding area, blocks a scenic view, or alters natural landforms. Steps to identify impacts to scenic resources, including any impacts from possible adaptation measures, include:

- Identify all scenic views to and through the proposed project site from public vantage points such as overlooks, access locations, beaches, trails, the Coastal Trail, public roads, parks, and if possible, map these views and view lines in relation to the location and maximum allowable elevation of the proposed project.
- Identify locations of the proposed project site that can support development and avoid or minimize impacts to scenic views from current and future vantage points. Overlay with development constraints (fault zones, landslides, steep slopes, property line setbacks, *etc.*) and with other coastal resource constraints.

3.2 Synthesize and assess development and resource constraints

After completing the detailed analysis of each coastal resource, the applicant should summarize the potential resource impacts under each sea level rise scenario identified in Step 1. This set of results, when combined with potential impacts to those coastal resources not affected by sea level rise, should give the applicant valuable information about the degree of risk posed to each coastal resource and to the development itself. If practical, for each sea level rise scenario, applicants should produce a constraints map illustrating the location and the extent of resource impacts that could occur over the life of the development. Based on the analysis of resource impacts and potential hazard risks over the life of the development, the applicant should develop an overlay identifying the development and resource constraints.

3.3 Identify areas suitable for development

The final part of this step is to identify the locations of the project site that could support some level of development without impacts to coastal resources and without putting the development at risk.

Expected outcomes from Step 3*: Upon completing this step, the applicant should have detailed information about the types of coastal resources on the project site and the level of risk that sea level rise poses to each resource under each sea level rise scenario, including resource locations and the extent of resource impacts that could occur over the life of the proposed project. This step should also provide an overlay of all development and resource constraints, and clearly identify the locations on the proposed project site that could support some level of development without impacts to coastal resources and without putting the development at risk.*

Step 4 – Identify project alternatives that avoid resource impacts and minimize risks to the project

By this step, applicants should have developed a set of factors based on the sea level rise hazards identified in Step 2, potential resource impacts identified in Step 3, and other site conditions (such as archaeological resources or fault lines) to identify the buildable areas that avoid both risk from coastal hazards and impacts to coastal resources. Hazard and resource avoidance is usually the preferred option, and, in many cases, applicants may find that the site is safe from sea level rise hazards for all the identified sea level rise scenarios and no further identification of project alternatives would be necessary in order to address sea level rise concerns.

For some cases, the site constraints may require consideration of project alternatives that fit with the available buildable area, without the use of protective structures. In these cases, one of the alternatives may be to replace what was initially being considered for the site. In other cases, development that is safe from hazards and is resource protective may be possible if certain adaptation strategies are used to modify the project over time and as the potential hazard areas increase or move closer to the project. For these cases, the possible adaptation measures would be included as part of the proposed project, along with necessary monitoring and triggers for implementing the adaptation options. In still other cases, hazard minimization may be the only feasible option for development on hazard constrained-sites. In all cases, projects must be sited and designed to address all applicable Coastal Act and LCP requirements, including any new requirements within LCPs that have been updated to adapt to sea level rise.

The results from the analysis of sea level rise scenarios should factor into the decisions made in this step. In particular, after looking at the results from Steps 2 and 3 as a whole, applicants can better decide the project changes, types of adaptation strategies, and design alternatives that would be most appropriate given the degree of risk posed by possible sea level rise and how long the development might be free from risk. The applicant also might identify triggers (*e.g.*, a certain amount of sea level rise) when certain adaptation measures should be implemented to reduce risk and/or impacts to coastal resources.

Importantly, land divisions and lot line adjustments in high hazard areas can change hazard exposure and should therefore be undertaken only when they can be shown to not worsen or create new vulnerability. In particular, no new lots or reconfigured lots with new development potential should be created if they cannot be developed without additional shoreline hazard risks.

Strategies to Avoid Resource Impacts and Minimize Risks

The best way to minimize risks to development and coastal resources is to avoid areas that are or will become hazardous as identified by the sea level rise scenarios analysis in the previous steps. Such avoidance often includes changes to the proposed project to bring the size and scale of the proposed development in line with the capacity of the project site. However, if it is not feasible to site or design a structure to completely avoid sea level rise impacts, the applicant may need to modify or relocate the development to prevent risks to the development or to coastal resources. Some changes, such as the use of setbacks, may be necessary at the outset of the project. Other changes, such as managed retreat or added floodproofing, may be useful as adaptive strategies that can be used after the initial project completion. Considerations involved in choosing and designing an appropriate adaptation strategy may include those listed below. See Chapter 7 for more information on specific adaptation measures. For a list of guidebooks, online clearinghouses, and other sea level rise adaptation resources, see Appendix C.

- **Assess Design Constraints:** Determine whether there are any significant site or design constraints that might prevent future implementation of possible sea level rise adaptation measures. Some project locations may be constrained due to lot size, sea level related hazards, steep slopes, fault lines, the presence of wetlands or other ESHA, or other constraints such that no safe development area exists on the parcel. Ideally, such parcels would be identified during the LCP vulnerability analysis, and the land use and zoning designations would appropriately reflect the constraints of the site. However, in some cases development may need to be permitted even if it cannot avoid all potential hazards. As stated above, care should be taken in these cases to avoid resource impacts and minimize risks as much as possible by developing and implementing a sea level rise adaptation plan for the proposed development. In creating this plan, it is important to identify any design constraints that will limit the ability to implement adaptation strategies in the future, as described below.

- **Identify Adaptation Options:** Identify possible adaptation strategies (such as those found in Chapter 7) for the proposed project, and evaluate each adaptation option for efficacy in protecting the development. Also, evaluate the consequences from each proposed adaptation measure to ensure it will not have adverse impacts on coastal and sensitive environmental resources, including visual impacts and public access.

  For example, an option that is often considered for sea level rise is to elevate the development or the structures that are providing flood protection. However, elevated structures will change the scenic quality and visual character of the area. Also, elevation of the main development may be of little long-term utility to the property owner if the supporting infrastructure, such as the driveways, roads, utilities or septic systems are not also elevated or otherwise protected. Elevation of existing levees or dikes can provide flood protection for an area of land and all the development therein. However, the foundation of the levee or dike must have been designed to support the additional height or else it may have to be expanded and the increased footprint of the foundation could have impacts on intertidal area, wetlands, or other natural resources. Thus, the long-term options for adaptation should be considered as part of any permit action, to ensure that current development decisions are not predetermining resource impacts in the future.

- **Ensure Sea Level Rise Design Flexibility:** If the likelihood of impacts is expected to increase with rising sea level, it may be necessary to design the initial project for some amount of sea level rise but to also include design flexibility that will allow future project changes or modifications to prevent impacts if the amount of sea level rise is more than anticipated in the initial design. Changes and modifications could include the use of foundation elements that will allow for building relocations or removal of portions of a building as it is threatened or reserving space to move on-site waste treatment systems away from eroding areas or areas that will be susceptible to a rising water table or increased flooding.

- **Develop Project Modifications**: Highly constrained sites may not be able to support the amount of development that an applicant initially plans for the site. Even a small building footprint may be at risk from flooding or erosion under high sea level rise scenarios. In such cases, it will be important to work closely with the appropriate planning staff to develop a project option that can minimize hazards from the identified sea level rise scenarios for as long as possible, and then incrementally retreat once certain triggers are met. Some examples of triggers could be that erosion is within some distance of the foundation, or monthly high tides are within some distance of the finished floor elevation. The time period for relocation or removing the structure would be determined by changing site conditions but relocation would most likely occur prior to the time period used in Step 1 to determine long-term site constraints.

- **Plan for Monitoring:** Develop a monitoring program or links to other monitoring efforts to ensure that the proposed adaptation measures will be implemented in a timely manner. Following a monitoring protocol and requirements for evaluating sea level rise impacts to coastal habitats over time can help to identify the triggers that would lead to revising project life, other project modifications or additional adaptation efforts.

Expected outcomes from Step 4*: This step may involve an iterative process of project modifications and reexamination of impacts, leading to one or more alternatives for the project site. The alternative that will minimize risks from coastal hazards and avoid or minimize impacts to coastal resources should be identified. Possible adaptation options could be identified and analyzed, if appropriate. If the site is very constrained, modifications to the expected project life might be suggested.*

Step 5 – Finalize project design and submit CDP application

After Step 4, the applicant should have developed one or more project alternatives and identified a preferred alternative. The alternatives should include adaptation strategies to minimize impacts if hazards cannot be avoided entirely. The CDP application step involves the following:

1. **Work with the planning staff to complete the CDP application**. Depending upon the proposed project and extent of prior interactions with the planning staff, the initial submittal may be the first time the planner has been provided with information about the general project or the preferred alternative. Once a proposed project is submitted, the coastal planner will need to become familiar with the project location, area around the project site, the proposed actions and the studies and analyses that have been undertaken in support of the application. The planner will review the application for completeness to ensure that there is sufficient information to analyze the project for all appropriate LCP or Coastal Act Chapter 3 policies. If analysis for sea level rise concerns is needed, the planner will also check that analyses for sea level rise risks have been included in the submittal. Much of the information developed in Steps 1-4 will be useful for the application process. The Suggested Filing Checklist for CDP Applications (located at the end of this chapter) covers the typical information that might be included in a CDP application necessary for planning review of the sea level rise aspects of the proposed project. Applicants who are unfamiliar with the permit process should consult the local government website, Coastal Commission website, or contact the appropriate district office for instructions on how to complete a CDP application.

   The review of an application might involve an iterative process, wherein planning staff requests more information about the proposed project, project alternatives, analysis of the hazards or identification of potential resource impacts to help in the review for compliance with the LCP or the Coastal Act. At the same time, planning staff may request that some of the technical staff review the submitted material to ensure that there is sufficient information in all technical information and analyses to support a decision on the proposed project. This process may be repeated until the application provides the studies, analysis and project review necessary for planning review.

2. **Submit a complete CDP application.** Once a complete application has been accepted, the planning staff will do a more thorough review and analysis of the potential hazards and resource impacts associated with the proposed project. Ideally, the planner will have requested all necessary project information at the filing stage. In some instances, additional information may be needed after the application has been accepted. This is normally limited to clarifications of some of the information or further details about some of the possible, but not preferred alternatives. During this stage in the CDP application process, the planner may identify necessary project modifications that were not part of the initial application, or identify various conditions that will be needed if the project is to be approved. Chapter 7 includes many of the possible project modifications and permit conditions that might be used to address sea level rise concerns and potential resource impacts.

   During the project analysis, the planning staff will review all submitted material, discussing the proposed project with other staff members, and obtaining further technical

review. Working with their supervisors and managers, they will also develop a staff recommendation and prepare a staff report that supports the proposed recommendation. Please consult the Coastal Commission website (http://www.coastal.ca.gov/cdp/cdp-forms.html) or contact your district office for instructions on how to complete a CDP application.

3. **Permit action.** Once the proposed project has been through planning review and a staff recommendation has been prepared, the proposed project will be brought to hearing before either the local planning commission or the California Coastal Commission. The outcome of the hearing process will be project approval, approval with conditions, or denial. Based on the regulatory decision, the project may be constructed, or additional modifications and condition requirements may have to be met.
4. **Monitor and revise.** CDP approvals may include conditions that require monitoring. Applicants should monitor the physical impacts of sea level rise on the project site, provide reports and updates to planning staff and introduce adaptive changes to the project in accordance with the permit and permit conditions.

Expected outcomes from Step 5*: This step, combined with supporting documentation from the previous steps, should provide a basis for evaluating the proposed project's hazard risks and impacts that can result from sea level rise. Such an analysis will provide one of the bases for project evaluation and complements the other resource evaluations and analyses that are part of a complete CDP application.*

Planning Process for Coastal Development Permits

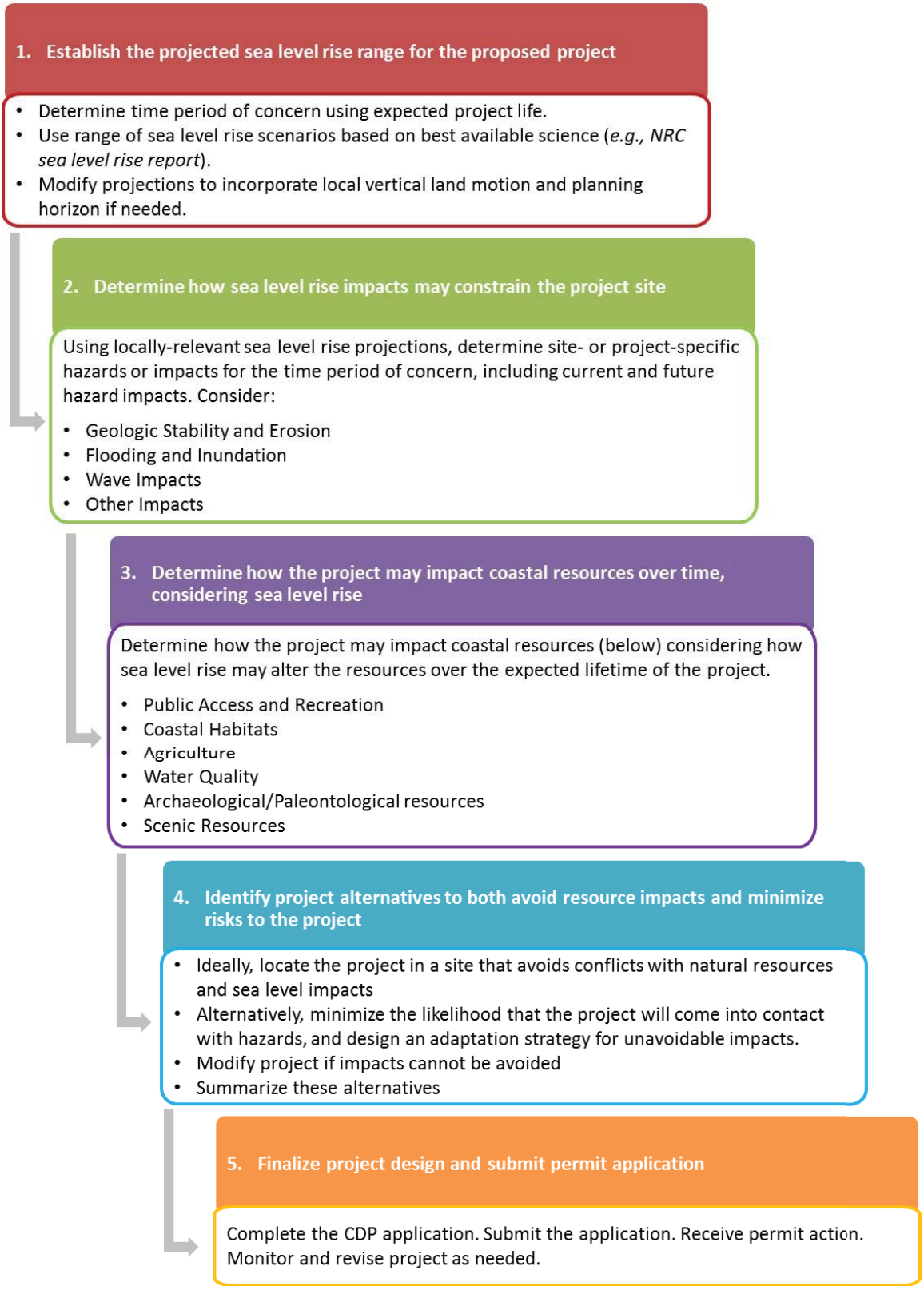
1. Establish the projected sea level rise range for the proposed project
• Determine time period of concern using expected project life.
• Use range of sea level rise scenarios based on best available science (e.g., NRC sea level rise report).
• Modify projections to incorporate local vertical land motion and planning horizon if needed.
2. Determine how sea level rise impacts may constrain the project site
Using locally-relevant sea level rise projections, determine site- or project-specific hazards or impacts for the time period of concern, including current and future hazard impacts. Consider:
• Geologic Stability and Erosion
• Flooding and Inundation
• Wave Impacts
• Other Impacts
3. Determine how the project may impact coastal resources over time, considering sea level rise
Determine how the project may impact coastal resources (below) considering how sea level rise may alter the resources over the expected lifetime of the project.
• Public Access and Recreation
• Coastal Habitats
• Agriculture
• Water Quality
• Archaeological/Paleontological resources
• Scenic Resources
4. Identify project alternatives to both avoid resource impacts and minimize risks to the project
• Ideally, locate the project in a site that avoids conflicts with natural resources and sea level impacts
• Alternatively, minimize the likelihood that the project will come into contact with hazards, and design an adaptation strategy for unavoidable impacts.
• Modify project if impacts cannot be avoided
• Summarize these alternatives
5. Finalize project design and submit permit application
Complete the CDP application. Submit the application. Receive permit action. Monitor and revise project as needed.

Figure 14. Flowchart for steps to address sea level rise in Coastal Development Permits

Suggested Filing Checklist for Sea Level Rise Analysis

- Proposed/Expected Project Life
- Sea Level Rise Projections used in Impacts Analyses
- Impacts Analyses (possibly from Vulnerability Assessment)
    - Structural and Geologic Stability
        - Identify current tidal datum
        - Perform Geotechnical Report and Erosion Analysis
        - Identify blufftop setback and safe building area
        - Show setback, safe building area and proposed project footprint (site maps)
    - Erosion Amount over Expected Project Life
        - Perform Coastal Processes Study and Erosion Analysis
        - Quantify total erosion amount for proposed project site
        - Show retreat along with proposed project footprint (site maps)
    - Flooding and Inundation Risks
        - Perform Coastal Processes Study and Wave Runup Analysis
        - Quantify flood elevation and flooding extent
        - Show flood extent with proposed project footprint (site map)
        - Show flood elevation on site profile, with proposed project elevation
        - Provide Flood Certificate if in FEMA designated 100-year Flood Zone
    - Tipping points for sea level rise impacts, specific to proposed project site
- Impacts to coastal resources (possibly from Environmental Assessment) for current conditions and changes due to sea level rise and related impacts
    - Public Access and Recreation
        - Show access resources and future changes (site maps)
    - Water Quality, surface and groundwater
        - Provide surface drainage patterns and runoff and future changes (site maps)
        - Provide zone of groundwater elevation
    - Coastal Habitats
        - Provide wetland delineation, ESHA determination, if appropriate
        - Provide boundary determinations or State Lands review, if appropriate
        - Show all coastal habitats and future changes (site maps)
    - Agricultural Resources
        - Show agricultural resources and future changes (site maps)
    - Natural Landforms
        - Show all natural landforms and future changes (site maps)
    - Scenic Resources
        - Show views from public access and future changes due to access changes
    - Overlay all coastal resources to establish areas suitable for development (site maps)
- Analysis of Proposed Project and Alternatives
    - Provide amount(s) of sea level rise used in project planning and design
    - Provide analysis of the proposed project and alternatives
    - Identify proposed current and future adaptation strategies
    - Show avoidance efforts (site map)
    - Identify hazard minimization efforts that avoid resource impacts (site maps)

Example for Addressing Sea Level Rise in Coastal Development Permits

To illustrate the process described in this chapter for how to address sea level rise in the CDP process, consider three example projects: a wetland restoration project, a new bluff-top residential development with a fronting beach, and a new wastewater treatment facility. These three examples will follow each of the recommended CDP steps, showing how the guidance could be applied in specific situations. Note that these are simplified examples used to demonstrate the process described in this chapter. Decisions about how to address various challenges presented by sea level rise will be more complex than those illustrated below, and the Coastal Commission encourages applicants to coordinate with staff as necessary and feasible throughout the process.

Step 1: Establish the projected sea level rise range for the proposed project

- *Wetland Restoration Project:* Sea level rise projection ranges should be chosen based on the goals of the project. For example, if wetland restoration efforts are intended as mitigation for a development project, the lifetime for the wetland restoration should be, at a minimum, the lifetime of the development project. For wetland restoration projects in which the desired outcome is the protection of the wetland in perpetuity, sea level rise ranges should be projected over a minimum of 100 years, with consideration of the intervening years as well as the even longer term for ongoing adaptive management.
- *Bluff-top Residential Development:* The lifetime of the project is assumed to be at least 75 years, unless the LCP specifies a different time period. High, low, and intermediate sea level rise projection ranges are established, appropriate for the proposed area over the assumed 75-year project life.
- *Wastewater Treatment Facility:* Wastewater treatment facilities are normally critical infrastructure. For this example, a minimum life of 100 years is assumed, unless the LCP specifies a different time period. High, low, and intermediate sea level rise projections ranges are established, appropriate for the proposed area over the assumed 100-year or longer project life.

Step 2: Determine how impacts from sea level rise may constrain the project site

- *Wetland Restoration Project:* Current topography of the wetland area is mapped, current barriers to inland migration are identified, and an analysis of erosion and flooding potential (and subsequent effects to wetland extent) is performed for various sea level rise scenarios. Potential changes to groundwater are evaluated. Potential changes in sediment flows or other physical properties as a result of changing conditions are examined. It is determined that in this case, open space exists behind the wetland to allow for inland migration over time.
- *Bluff-top Residential Development:* The average long-term beach and bluff retreat rate, erosion rate due to various sea level rise scenarios, and erosion potential from 100-year storms and other extreme events are determined. Beach and bluff erosion will vary with sea level rise rates. The geologic stability of the bluff over the life of the development is analyzed assuming that no protective structure (such as a seawall) either exists or will be built.

- *Wastewater Treatment Facility:* Erosion and flooding potential over the lifetime of the facility under both a low and a worst-case scenario sea level rise projection are analyzed, as are current and future wave runup and storm impacts for 100-year storms. The geologic stability of the site over the life of the facility is analyzed assuming that no protective structure either exists or will be built. Potential damage to infrastructure (for example corrosion due to saltwater intrusion) is examined.

Step 3: Determine how the project may impact coastal resources, considering the influence of sea level rise upon the landscape over time

- *Wetland Restoration Project:* Coastal resources present in the proposed project site are mapped and sea level rise impacts to these resources are analyzed over the lifetime of the project. It is unlikely that the project will have any adverse impacts on coastal resources. Barriers to wetland migration are examined and it is determined in this case that enough open space currently exists to allow for the wetland to migrate inland over time. The few barriers that exist can be modified in the future, if necessary. This will allow for continued maintenance of habitat area and ecosystem services.
- *Bluff-top Residential Development:* Maps are developed that identify scenic viewsheds, the bluff extent, and adjacent coastal habitats including the fronting beach, and descriptions of each are provided. Opportunities for public access are identified. Impacts to each of these resources as a result of sea level rise are analyzed, as are impacts that would result from the development project. It is determined that the development has the potential to result in the loss of a fronting beach if a protective structure is installed. However, development setbacks are designed to ensure that no such structure is planned over the lifetime of the development under any sea level rise scenario.
- *Wastewater Treatment Facility:* Maps are developed that identify coastal resources in the area and impacts to these resources resulting from sea level rise are analyzed. As with the bluff-top development, any protective structure would have detrimental effects to the fronting beach, but no such structure is determined to be necessary. Any potential impacts to adjacent habitat areas or to water quality as a result of damage to infrastructure (for example sewage outflow or backup of seawater into the system) are examined under the range of sea level rise projections for the life of the facility.

Step 4: Identify project design alternatives that avoid resource impacts and minimize risks to the project

- *Wetland Restoration Project:* In this example, there are no concerns related to detrimental impacts to coastal resources as a result of this project. Natural barriers will be removed through grading and contouring of the land to ensure that the wetland has the ability to migrate inland with sea level rise and that hydrologic function will be maintained. Inland areas are protected into the future to ensure the space will be open for migration. Additionally, a plan is included to monitor changes in sea level, sediment dynamics, and overall health of the wetland so that adaptive management options can be applied as needed.

- *Bluff-top Residential Development:* The optimal site for a bluff-top residential development is one that avoids the hazards identified in Step 2 and impacts to coastal resources identified in Step 3 over the life-time of the project. If the proposed site does not avoid risks, alternative locations on the project sites should be identified and examined. If no such location exists, efforts should be made to minimize hazards and impacts to resources, or the project should be denied. Minimization efforts may include: building with an extra setback from the bluff-face, developing a managed retreat plan, and designing buildings to be easily relocated. If the safe building envelope will not be sufficient for a reasonable-sized building, local governments could consider allowing reduced setbacks on portions of the site located away from the bluff face (*e.g.*, side or front yard setbacks), reduced off-street parking, additional height on safe portions of the site, or other development that doesn't require shore protection. No seawall is planned as such a device would result in the loss of the fronting beach. A plan to monitor rates of erosion at various places along the bluff as well as any impacts to adjacent resources is developed, and erosion rates/scenarios that would trigger the need for retreat are identified.
- *Wastewater Treatment Facility:* The optimal site for a wastewater treatment facility is one that avoids the hazards identified in Step 2 and impacts to coastal resources identified in Step 3 over the life-time of the project. If the proposed site does not avoid risks, alternative sites should be identified and examined. If no such site exists, efforts should be made to minimize hazards and impacts to resources. Minimization efforts may include: building the facility further back from the beach, elevating outflow pipes, and adding one-way valves to prevent backflow of sea-water into the system. A plan to monitor erosion rates along the beach as well as wave and storm impacts and any impacts to coastal resources caused by the facility is developed.

Step 5: Finalize project design and submit CDP application

- *Wetland Restoration Project:* The best site and design option is chosen and presented to the Commission or local government for the permit process. Application includes likely options for adaptive management to maintain wetlands and key monitoring needed to examine ongoing wetland function.
- *Bluff-top Residential Development:* The best site and design option is chosen and presented to the Commission or local government for the permit process. Application includes analyses of hazard and resource risks and any plans for adaptive project designs and proposed monitoring.
- *Wastewater Treatment Facility:* The best site and design option is chosen and presented to the Commission or local government for the permit process. Application includes analyses of hazards and resource risk and plans for site monitoring.

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Chapter 7

Adaptation Strategies

Chapters 5 and 6 provide guidance on the sequential processes for addressing sea level rise in Local Coastal Programs (LCPs) and Coastal Development Permits (CDPs). This chapter describes some of the specific adaptation strategies to consider in these planning and development review processes. Given the range of impacts that could occur as a result of sea level rise, and the uncertainties surrounding projections of sea level rise over the lifetimes of many coastal projects, communities, planners, coastal managers and project applicants will need to use adaptation strategies to effectively address coastal hazard risks, and protect coastal resources over time.

As described in Chapters 5 and 6, adaptation strategies should be chosen based on the specific risks and vulnerabilities of a region or project site and the applicable Coastal Act and LCP requirements, with due consideration of local priorities and goals. Adaptation strategies may involve modifications to land use plans, regulatory changes, project modifications, or permit conditions that focus on avoidance or minimization of risks and the protection of coastal resources.

Some adaptation strategies may require land use plans or proposed projects to anticipate longer-run impacts now, such as assuring that critical infrastructure is built to last a long time without being put in danger, or rezoning hazardous areas as open space. Other adaptation strategies may build adaptive capacity into the plan or project itself, so that future changes in hazard risks can be effectively addressed while ensuring long-term resource protection. In most cases, especially for LCP land use and implementation plans, multiple adaptation strategies will need to be employed. For projects, adaptation strategies may be addressed through initial siting and design and through conditions that provide for specific adaptation over time.

The next sections provide an overview of the general categories of adaptation options, followed by a description of various specific adaptation strategies organized by type of coastal resource, as outlined in Chapter 3 of the California Coastal Act.

The adaptation options described in this chapter are intended to provide guidance for potential LCP and permitting strategies. Not all strategies listed here will be appropriate for every jurisdiction, nor is this an exhaustive list of options. However, as described in Chapters 5 and 6, all local governments and all project applicants should analyze the possible effects of sea level rise and evaluate how the strategies in this chapter, or additional supplemental strategies, could be implemented in LCPs or CDPs to minimize the adverse effects of sea level rise.

GENERAL ADAPTATION CATEGORIES

There are a number of options for how to address the risks and impacts associated with sea level rise. Choosing to “do nothing” or following a policy of “non-intervention” may be considered an adaptive response, but in most cases, the strategies for addressing sea level rise hazards will require proactive planning to ensure protection of coastal resources and development. Such proactive adaptation strategies generally fall into three main categories: protect, accommodate, and retreat.

For purposes of implementing the Coastal Act, no single category or even specific strategy should be considered the “best” option as a rule. Different types of strategies will be appropriate in different locations and for different hazard management and resource protection goals. The effectiveness of different adaptation strategies will vary across both spatial and temporal scales. In many cases, a hybrid approach that uses strategies from multiple categories will be necessary,

and the suite of strategies chosen may need to change over time. As discussed later in the document, the legal context of various options will also need to be considered in each situation and ultimately, adaptive responses will need to be consistent with the Coastal Act. Nonetheless, it is useful to think about the general categories of adaptation strategies to help frame the consideration of land use planning and regulatory options in specific communities and places along the coast.

Protect: Protection strategies refer to those strategies that employ some sort of engineered structure or other measure to defend development (or other resources) in its current location without changes to the development itself. Protection strategies can be further divided into "hard" and "soft" defensive measures or armoring. "Hard" armoring refers to engineered structures such as seawalls, revetments, and bulkheads that defend against coastal hazards like wave impacts, erosion, and flooding. Such armoring is a fairly common response to coastal hazards, but it can result in serious negative impacts to coastal resources, particularly as sea level rises. Most significantly, hard structures form barriers that impede the ability of natural beaches and habitats to migrate inland over time. If they are unable to move inland, public recreational beaches, wetlands, and other habitats will be lost as sea level continues to rise. This process is commonly referred to as "passive erosion," which is the narrowing of beaches due to the fact that the back of the beach on an eroding shoreline has been fixed in place (Flick *et al*. 2012). Other detrimental impacts may include negative visual impacts or interference with other ecosystem services.

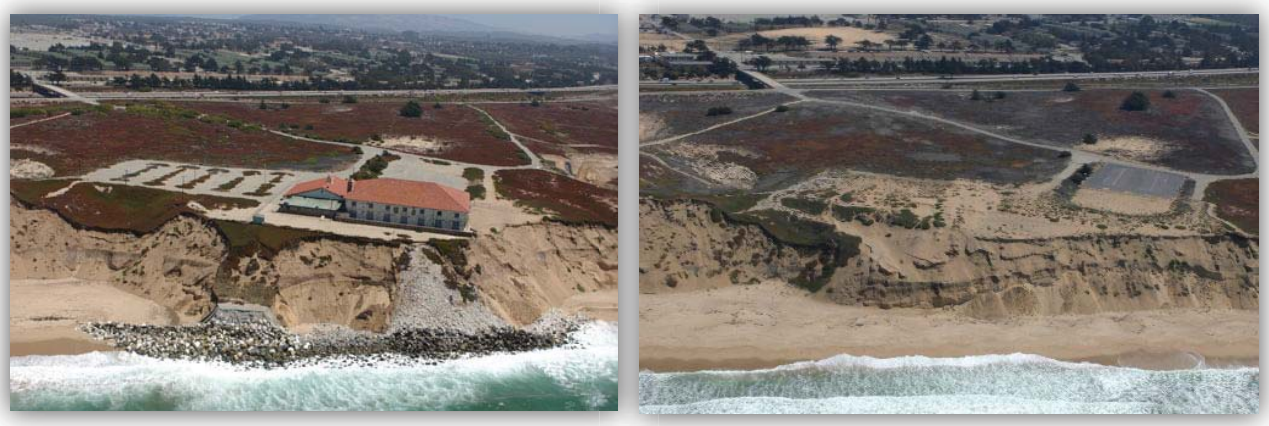

Figure 15. Photo depicting passive erosion. (*Left*) Passive erosion in front of a revetment at Fort Ord, illustrating the loss of beach where the development prevents the shoreline from migrating landward. The beach continues to migrate inland on either side of the revetment. (*Right*) Recovery of the beach following removal of the revetment and blufftop structure. (*Source:* California Coastal Records Project).

"Soft" armoring refers to the use of natural or "green" infrastructure like beaches, dune systems, wetlands, and other systems to buffer coastal areas. Strategies like beach nourishment, dune management, or the construction of "living shorelines" capitalize on the natural ability of these systems to protect coastlines from coastal hazards while also providing benefits such as habitat, recreation area, more pleasing visual impacts, and the continuation or enhancement of ecosystem services. The engineering of green infrastructure is a somewhat newer concept in some cases, and because of this, the effectiveness of different strategies in different types of environments is not necessarily well-known or tested. In cases in which natural infrastructure might not be

completely effective or may not be preferred, a hybrid approach using both hard and natural infrastructure could be considered. As described in Principle 10 of this Guidance and in the *Safeguarding California* plan (CNRA 2014), priority should be given to options that protect, enhance, and maximize coastal resources and access, including giving full consideration to innovative nature-based approaches such as living shoreline techniques or managed/planned retreat. Although the Coastal Act clearly provides for potential protection strategies for "existing development", it also directs that new development be sited and designed to not require future protection that may alter a natural shoreline.

Accommodate: Accommodation strategies refer to those strategies that employ methods that modify existing developments or design new developments to decrease hazard risks and thus increase the resiliency of development to the impacts of sea level rise. On an individual project scale, these accommodation strategies include actions such as elevating structures, retrofits and/or the use of materials meant to increase the strength of development, building structures that can easily be moved and relocated, or using extra setbacks. On a community-scale, accommodation strategies include any of the land use designations, zoning ordinances, or other measures that require the above types of actions, as well as strategies such as clustering development in less vulnerable areas or requiring mitigation actions to provide for protection of natural areas even as development is protected. As with protection strategies, some accommodation strategies could result in negative impacts to coastal resources. Elevated structures may block coastal views or detract from community character; pile-supported structures may, through erosion, develop into a form of shore protection that interferes with coastal processes, blocks access, and, at the extreme, results in structures looming over or directly on top of the beach.

Figure 16. Photo depicting "managed retreat" and restoration. Surfers' Point Managed Shoreline Retreat project in which the parking lot was moved back and beach area was restored. (*Aerial composite by Rick Wilborne (February 28, 2013); photo courtesy of Surfrider Foundation*)

Retreat: Retreat strategies are those strategies that relocate or remove existing development out of hazard areas and limit the construction of new development in vulnerable areas. These strategies include land use designations and zoning ordinances that encourage building in more resilient areas or gradually removing and relocating existing development. Acquisition and buy-out programs, transfer of development rights programs, and removal of structures where the right to protection was waived (*i.e.*, via permit condition) are examples of strategies designed to encourage managed retreat.

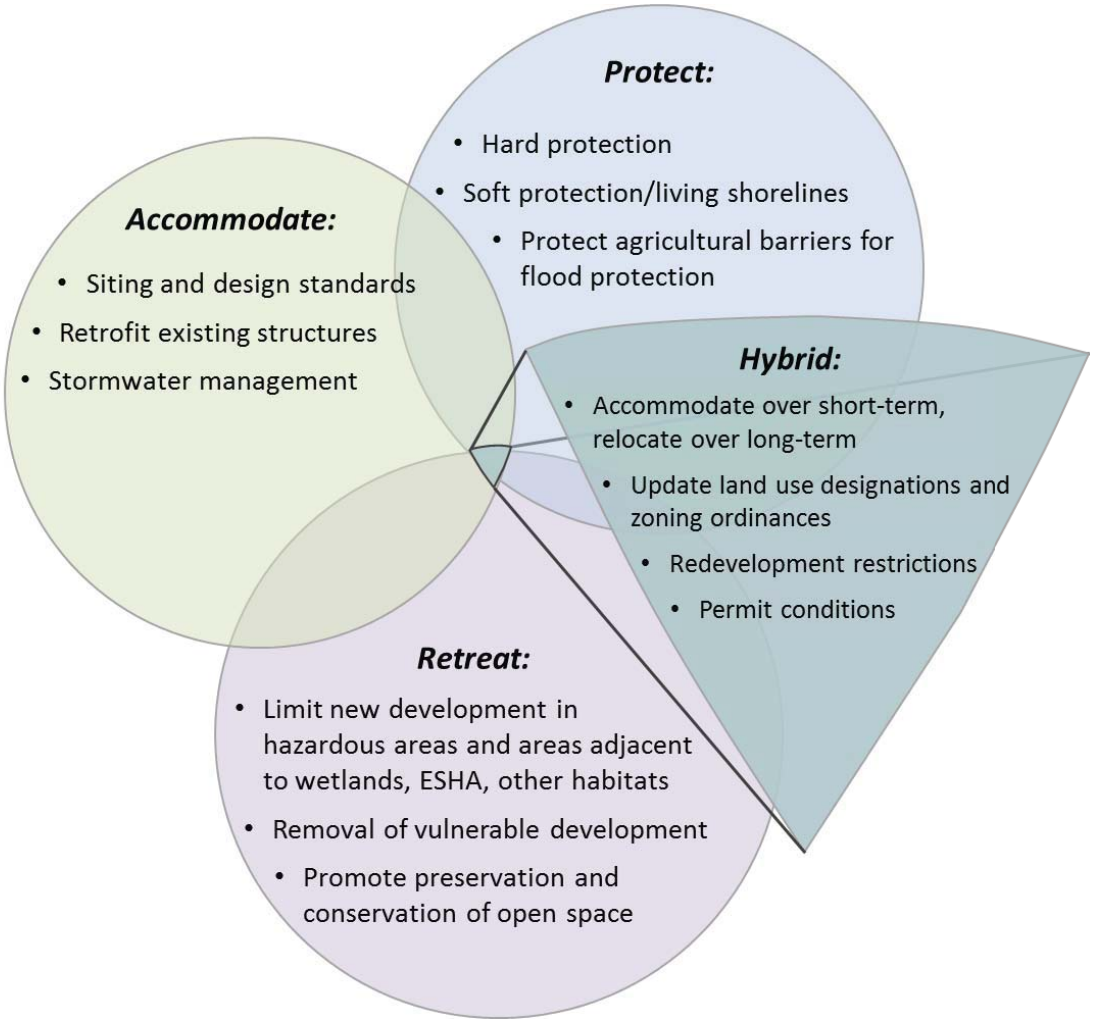
Protect:
• Hard protection
• Soft protection/living shorelines
• Protect agricultural barriers for flood protection
Accommodate:
• Siting and design standards
• Retrofit existing structures
• Stormwater management
Hybrid:
• Accommodate over short-term, relocate over long-term
• Update land use designations and zoning ordinances
• Redevelopment restrictions
• Permit conditions
Retreat:
• Limit new development in hazardous areas and areas adjacent to wetlands, ESHA, other habitats
• Removal of vulnerable development
• Promote preservation and conservation of open space

Figure 17. Examples of general adaptation strategies

SPECIFIC ADAPTATION STRATEGIES

The following sections, organized by category of coastal resource, present measures that local governments and coastal planners should consider including in their LCPs or individual CDPs. The purpose of this organization is to allow coastal managers and project applicants to easily find strategies that will help address the specific resource vulnerabilities identified in Steps 1-3 of the LCP and CDP processes laid out in Chapters 5 and 6. In the development of LCP policies, local governments should use adaptation measures that best implement the statewide resource protection and hazard policies of the Coastal Act at the local level given the diverse geography and conditions of different areas.

As part of identifying adaptation strategies, local governments should carefully examine the potential impacts to coastal resources that could occur from various adaptation strategies. Some adaptation strategies will need to be implemented incrementally over time as conditions change, and many strategies will need to be implemented through both the LCP and CDP to be effective. For each issue area, there is a description of potential impacts that could occur due to sea level rise and a list of adaptation tools or actions to minimize impacts. To skip to a topic, click on the links below.

A. Coastal Development and Hazards
B. Public Access and Recreation
C. Coastal Habitats, ESHA, and Wetlands
D. Agricultural Resources
E. Water Quality and Supply
F. Archaeological and Paleontological Resources
G. Scenic and Visual Resources

The lists in these sections should be considered neither checklists from which all options need to be used, nor exhaustive lists of all possible adaptation strategies. Sea level rise adaptation is an evolving field, and policy language, cost considerations, effectiveness of various strategies, and other topics are continuing to be developed. Planners, applicants, and partners will need to think creatively and adaptively respond to changing conditions, new science, and new adaptation opportunities, and the Coastal Commission will continue to support and collaborate on these efforts.

Additionally, sea level rise planning may involve a number of trade-offs among various competing interests, and no single adaptation strategy will be able to accomplish all planning objectives. Economic and social implications of various adaptation options will likely play into the planning process at the local level. The important point is to analyze current and future risks from sea level rise, determine local priorities and goals for protection of coastal resources and development in light of Coastal Act requirements, and identify what land use designations, zoning ordinances, and other adaptation strategies can be used to meet those goals.

A. Coastal Development and Hazards

The Coastal Act requires that new development be sited and designed to be safe from hazards and to not adversely impact coastal resources (Coastal Act Sections 30235 and 30253). The main goals that relate to hazards and coastal development are:

- Update land use designations, zoning maps, and ordinances to account for changing hazard zones
- Include sea level rise in hazard analyses and policies
- Plan and locate new development to be safe from hazards, not require protection over its entire lifespan, and be protective of coastal resources
- Incorporate sea level rise adaptation into redevelopment policies
- Encourage the removal of development that is threatened by sea level rise
- Use "soft" or "natural" solutions as a preferred alternative for protection of existing endangered structures
- Limit bluff and shoreline protective devices to protect existing endangered structures
- Require special considerations for critical infrastructure and facilities
- Protect transportation infrastructure

Chapter 3 of the Guidance covers the impacts to coastal development that might result from sea level rise. Certified LCPs should already have policies and standards to assure that coastal development is safe over its anticipated lifetime and that it does not adversely impact other coastal resources. However, LCP policies and standards may need to be updated in light of new knowledge and to consider sea level rise hazards. Adaptation options have been developed to support the development goals of the Coastal Act through both LCP policies and CDP conditions, and the following strategies cover a range of options for addressing the identified goals of the Coastal Act.

Goal: Update land use designations, zoning maps, and ordinances to account for changing hazard zones

A.1 **Establish mapped hazard zones or overlays:** Update land uses and zoning requirements to minimize risks from sea level rise in identified hazard zones or overlay areas. For example, limit new development in current and future sea level hazard zones and encourage removal of existing development when threatened.

A.1a **Identify zones that require a more rigorous sea level rise hazards analysis**: Specify areas where a closer analysis of sea level rise is necessary at the permit application stage to avoid or minimize coastal hazards and impacts to coastal

resources. Ensure that the most up-to-date information on sea level rise is incorporated in such analyses.

Goal: Include sea level rise in hazard analyses and policies

A.2 **Update policies to require sea level rise to be included in hazard analyses and management plans**: LCP policies should include requirements to analyze projected sea level rise. Consider specific projection scenarios to be analyzed. (See Chapter 3 of the Guidance for a description of scenario planning.) LCPs could also specify which analyses are required for various types of projects/development (see Step 2 of Chapters 5 and 6 or Appendix B for suggested analyses).

A.2a **Site-specific evaluation of sea level rise**: Update policies, ordinances, and permit application requirements to include a required site-specific evaluation of coastal hazards due to sea level rise over the full projected life of any proposed development. Analyses should be conducted by a certified Civil Engineer or Engineering Geologist with expertise in coastal processes.

A.2b **Incorporate wave runup zones and sea level rise in coastal flood hazard maps:** Develop coastal flood maps that include areas that will be subject to wave action and flooding due to sea level rise. These maps may be able to rely upon existing flood maps, such as the FEMA Flood Insurance Rate Maps, for current flood areas and base conditions, but should be augmented to include future conditions, including sea level rise, likely to occur through the life of proposed new development.

A.2c **Incorporate sea level rise into calculations of the Geologic Setback Line**: Update geotechnical report requirements for establishing the Geologic Setback Line (bluff setback) to include consideration of bluff retreat due to sea level rise in addition to historic bluff retreat data, future increase in storm or El Niño events, and any known site-specific conditions. The report should be completed by a licensed Geotechnical Engineer or an Engineering Geologist.

A.2d **Include sea level rise in wave runup, storm surge, and tsunami hazard assessments**[46]: Sea level rise should be included in wave runup analyses, including storm event and tsunami hazard assessments. This should include evaluating tsunami loads/currents on maritime facilities and coastal structures. Since tsunami wave runup can be quite large, sea level rise projections of only a few inches may not have a large impact on these assessments. However, for time periods or scenarios where sea level rise projections are large (perhaps 1 ft or more), it would be appropriate to include sea level rise because it could change the results to a significant degree.

[46] Tsunami evacuation maps are based upon current sea level conditions and they will need to be updated with changes in sea level.

A.3 Establish shoreline management plans to address long-term shoreline change due to sea level rise: Create policies that require a management plan for priority areas that are subject to sea level rise hazards, and incorporate the plan into the larger LCP if applicable. Similar to an LCP, shoreline management plans generally include the short and long term goals for the specified area, the management actions and policies necessary for reaching those goals, and any necessary monitoring to ensure effectiveness and success. Incorporate strategies necessary to manage and adapt to changes in wave, flooding, and erosion hazards due to sea level rise.

Goal: Plan and locate new development to be safe from hazards, not require protection over its entire lifespan, and be protective of coastal resources

A.4 Limit new development in hazardous areas: Restrict or limit construction of new development in zones or overlay areas that have been identified or designated as hazardous areas to avoid or minimize impacts to coastal resources and property from sea level rise impacts.

A.5 Cluster development away from hazard areas: Concentrate development away from hazardous areas. Update any existing policies that cluster development to reflect additional hazard zones due to sea level rise.

A.5a **Concentration of development/smart growth**: Require development to concentrate in areas that can accommodate it without significant adverse effects on coastal resources. This strategy is applicable for community wide planning through an LCP, but may also apply to CDPs for subdivisions or for larger developments involving large or multiple lots.

A.5b **Transfer of Development Rights programs (TDR)**: Restrict development in one area ("sending area") and allow for the transfer of development rights to another area more appropriate for intense use ("receiving area"). LCPs can establish policies to implement a TDR program to restrict development in areas vulnerable to sea level rise and allow for transfer of development rights to parcels with less vulnerability to hazards. A TDR program can encourage the relocation of development away from at-risk locations, and may be used in combination with a buy-out program.

A.6 Develop adequate setbacks for new development: Ensure structures are set back far enough inland from the beach or bluff edge such that they will not be endangered by erosion (including sea level rise induced erosion) over the life of the structure, *without the use of a shoreline protective device*. When used to address future risk, setbacks are normally defined by a measurable distance from an identifiable location such as a bluff edge, line of vegetation, dune crest, or roadway. Establish general guidance and criteria for setbacks in LCPs that consider changes in retreat due to sea level rise. Require detailed, site-specific analyses through LCPs and CDPs to determine the size of the setback, taking into consideration sea level rise and establish the expected life of the

structure (for example, the time period over which the setback should be effective).

Figure 18. Photo depicting a development setback in Pismo Beach. (*Source:* California Coastal Records Project)

A.7 **Limit subdivisions in areas vulnerable to sea level rise**: Prohibit any new land divisions, including subdivisions, lot splits, lot line adjustments, and/or certificates of compliance that create new beachfront or blufftop lots unless the lots can meet specific criteria that ensure that when the lots are developed, the development will not be exposed to hazards or pose any risks to protection of coastal resources.

A.8 **Update development siting, code, and design standards to avoid, minimize, or reduce risks from coastal hazards and extreme events**: Establish and implement building codes and standards for building siting and construction that avoid or minimize risks from flooding and erosion and increase resilience to extreme events within sea level rise hazard zones. Such standards and applicable building code provisions should be included in LCPs as additional development controls in areas that are identified in the LCP as hazard areas, and applied in specific projects through a CDP.

A.8a **Update flood protection measures to incorporate both FEMA and Coastal Act requirements:** Require new development located in areas subject to current or future flood/wave action to be sited and designed to be capable of withstanding such impacts in compliance with both FEMA and Coastal Act requirements. For example, ensure that implementation of adaptation measures such as elevation of habitable areas, break-away walls, *etc*. will be consistent with both LCP and FEMA provisions.

A.8b **Limit basements and first floor habitable space**: Where applicable, in areas likely to be subject to current or future flood/wave action, revise residential building standards to prohibit habitable space at elevations subject to wave/flood risk. Specifically address potential impacts of basements on long-range adaptation options such as landward relocation or removal.

A.8c **Evaluate impacts from flood protection measures:** Require new development that must be located in areas likely subject to current or future flood/wave action or elevated groundwater to evaluate potential impacts to adjacent or nearby properties from all proposed structural flood protection measures to ensure that these measures will not create adverse direct and/or cumulative impacts either on-site or off-site.

A.9 Analyze options for removal when planning and designing new development: Design options should not place an undue burden on future property owners or coastal resources. For new development in high hazard areas or resource-constrained areas where managed retreat might be an appropriate option at some time in the future, ensure that foundation designs or other aspects of the development will not preclude future incremental relocation or managed retreat. Foundation and building elements, such as deepened perimeter foundations, caissons or basements, may be difficult to remove in the future, or their removal may put adjacent properties at risk. Alternative design options should be considered, and employed if site conditions allow.

A.9a **Develop a plan to remove or relocate structures that become threatened:** Require new development authorized through a CDP that is subject to wave action, erosion, or other hazards to be removed or relocated if it becomes threatened in the future.

A.9b **Identify triggers for incremental removal of structures on constrained lots**: When a lot is not large enough to accommodate development that avoids coastal hazards for the expected life of the development, develop a project option that minimizes hazards from the identified sea level rise scenarios for as long as possible, and then requires incremental retreat once certain triggers are met.

Triggers for relocation or removal of the structure would be determined by changing site conditions such as when erosion is within a certain distance of the foundation; when monthly high tides are within a certain distance of the finished floor elevation; when building officials prohibit occupancy; or when the wetland buffer area decreases to a certain width.

A.9c **Avoid shoreline protection for new development:** Require CDPs for new development in hazardous locations to include as a condition of approval a waiver of rights to future shoreline protection that would substantially alter natural landforms or cause other adverse coastal resource impacts.

A.9d **Limit the use of foundations or basements that can interfere with coastal processes:** In locations where foundation or building elements, such as deepened perimeter foundations, caissons or basements may be exposed to wave action through rising sea level or erosion, require analysis of less extensive foundation or building options.

A.9e **Develop triggers for foundation and structure removal:** If no less damaging foundation alternatives are possible, ensure that the foundation design allows for incremental removal as the foundation elements become exposed, and develop pre-established triggers, for example when the bluff edge or shoreline comes within a certain distance of the foundation, for incremental or complete removal that will avoid future resource impacts.

Figure 19. Photo depicting eroding bluff and exposed caissons in Encinitas, CA. (*Photograph by Lesley Ewing*)

A.10 Ensure that current and future risks are assumed by the property owner: New development should be undertaken in such a way that the consequences from development in high hazard areas will not be passed on to public or coastal resources. Recognize that over time, sea level rise will cause the public trust boundary to move inland. Establish standards, permit conditions, and deed restrictions that ensure that current and future risks are assumed by the property owner. Consider policies that would encourage or require property owners to set aside money, such as in the form of a bond, as a contingency if it becomes necessary to modify, relocate, or remove development that becomes threatened in the future.

A.11 Real estate disclosure: Require sellers of real estate to disclose permit conditions related to coastal hazards, or property defects or vulnerabilities, including information about known current and potential future vulnerabilities to sea level rise, to prospective buyers prior to closing escrow.

Goal: Incorporate sea level rise adaptation into redevelopment policies

A.12 Avoid the expansion or perpetuation of existing structures in at-risk locations: On an eroding shoreline, the seaward portions of an existing structure may become threatened as the setback or buffer zone between the structure and the mean high tide line or bluff edge is reduced due to erosion of the beach or bluff. When the seaward portion of the structure no longer meets the standards or setback that would be required for new development, it becomes a "non-conforming" structure for purposes of redevelopment policies and regulations. The following should be considered, as consistent with the Coastal Act, FEMA policies, and other relevant standards, to address existing non-conforming development to avoid the need for shoreline or bluff protective devices and associated impacts to coastal resources.

A.12a **Update non-conforming structure policies and definitions**: Develop policies and regulations to define non-conforming development in the area between the sea and the first coastal roadway or other known hazard zones to avoid perpetuating development that may become at risk and require a new protective device or extend the need for an existing protective device.

A.12b **Limit redevelopment or upgrades to existing structures in at risk locations**: Use redevelopment policies or regulations to limit expansions, additions, or substantial renovations of existing structures in danger from erosion. Require removal of non-conforming portions of the existing structure, when possible, when a remodel or renovation is proposed.

A.12c **Limit foundation work within the geologic setback area:** To facilitate removal of non-conforming portions of an existing structure, use LCP regulations and CDPs to limit new or replacement foundations or substantial improvements, other than repair and maintenance, to the existing foundation when located seaward of the Geologic Setback line. Approve significant new foundation work only when it is located inland of the setback line for new development and when it will not interfere with coastal processes in the future.

A.12d **Limit increases to existing non-conformities:** Use LCP regulations and CDPs to allow non-exempt repair and maintenance and modifications only if they do not increase the size or degree of non-conformity of the existing structure. For shoreline or blufftop development, any decrease in the existing non-conforming setback would increase the degree of non-conformity.

A.12e **Limit additions to non-conforming structures:** Use LCP regulations and CDPs to acknowledge that additions to existing structures should be considered new development that must conform to the standards for new development including but not limited to avoiding future protective devices. Consider limitations on the size of additions unless non-conforming portions of the structure are removed.

A.12f **Address existing protection of non-conforming structures:** Use LCP regulations and CDP conditions to put current and future property owners on notice that if there is currently shoreline or bluff protection for an existing structure, the structure is likely at-risk and improvements to that structure in its current location may be limited. Also, consider acknowledging that any rights to

retain the existing protective device(s) apply only to the structure that existed at the time the protective device was constructed or permitted.

A.13 Redevelopment of existing structures: Define "redevelopment" as, at a minimum, replacement of 50% or more of an existing structure. Other options that may be used to define what constitutes redevelopment or a replacement structure could include 1) limits on the extent of replacement of major structural components such as the foundation or exterior walls, or 2) improvements costing more than 50% of the assessed or appraised value of the existing structure. The redevelopment definition should take into consideration existing conditions and pattern of development, potential impacts to coastal resources, and the need for bluff or shoreline protective devices if the structure remains in its current, non-conforming location.

A.13a **Require redevelopment to meet the standards for new development:** Use LCPs and CDPs to require that renovations meeting the threshold for redevelopment should not be approved unless the entire structure meets the standards for new development, including but not limited to a waiver of right to protection. Specify that if any existing non-conforming elements are permitted to remain, those non-conforming elements are not subject to rights to protection pursuant to Coastal Act Section 30235.

A.13b **Include cumulative improvement or additions to existing structures in the definition of redevelopment:** Use LCP regulations to acknowledge that demolition, renovation, or replacement of less than 50% (or less) of an existing structure constitutes redevelopment when the proposed improvements would result cumulatively in replacement of more than 50% of the existing structure from an established date, such as certification of the LUP.

A.14 Remove existing shoreline protective devices: On properties with existing shoreline protective devices, use regulations to require removal of the protective device when the structure requiring protection is redeveloped or removed. If removal is not possible, require a waiver of any rights to retain the protective device to protect any structure other than the one that existed at the time the protective device was constructed or permitted.

Goal: Encourage the removal of development that is threatened by sea level rise

A.15 Use Rolling Easements: The term "rolling easement" refers to the policy or policies intended to allow coastal lands and habitats including beaches and wetlands to migrate landward over time as the mean high tide line and public trust boundary moves inland with sea level rise. Such policies often restrict the use of shoreline protective structures (such as the "no future seawall" limitation sometimes used by the Commission), limit new development, and encourage the removal of structures that are seaward (or become seaward over time) of a designated boundary. This boundary may be designated based on such variables as the mean high tide line, dune vegetation line, or other dynamic line or legal requirement. Despite the term "rolling easements," not all of the strategies related to rolling easements actually involve the use of recorded easements.

A.16 **Develop an incentive program to relocate existing development at risk**: Provide incentives to relocate development out of hazardous areas and to acquire oceanfront properties damaged by storms, where relocation is not feasible. Consider creating a relocation fund through increased development fees, *in lieu* fees, or other funding mechanisms.

A.17 **Transfer of Development Rights programs (TDR)**: See Strategy A.5b above.

A.18 **Acquisition and buyout programs**: Acquisition includes the acquiring of land from the individual landowner(s). Structures are typically demolished or relocated, the property is restored, and future development on the land is restricted. Such a program is often used in combination with a TDR program that can provide incentives for relocation. Undeveloped lands are conserved as open space or public parks. LCPs can include policies to encourage the local government to establish an acquisition plan or buyout program to acquire property at risk from flooding or other hazards.

Goal: Use "soft" or "natural" solutions as a preferred alternative for protection of existing endangered structures

A.19 **Require the use of green infrastructure as a preferred alternative**: Under appropriate shoreline conditions, require or encourage development to use "soft" or "natural" solutions or "living shorelines" as an alternative to the placement of hard shoreline protection in order to protect development or other resources and to enhance natural resource areas. Examples of soft solutions include vegetative planting, dune restoration, and sand nourishment.

A.19a **Establish a beach nourishment program and protocols**: New policies may be needed to address increased demand or need for beach nourishment with sea level rise. Policies within an LCP may identify locations where nourishment may be appropriate; establish a beach nourishment program and protocols for conducting beach nourishment; establish criteria for the design, construction, and management of the nourishment area; and/or establish measures to minimize adverse biological resource impacts from deposition of material, such as sand compatibility specifications, timing or seasonal restrictions, and identification of environmentally preferred locations for deposits. Beach nourishment programs should also consider how nourishment options may need to change over time as sea level rises.

A.19b **Dune management**: Establish management actions to maintain and restore dunes and natural dune processes. Dunes provide buffers against erosion and flooding by trapping windblown sand, storing excess beach sand, and protecting inland areas, and they also provide habitat. This is likely most effective for areas with some existing dune habitat and where there is sufficient space to expand a foredune beach for sand exchange between the more active (beach) and stable (dune) parts of the ecosystem. LCPs can identify existing dune systems and develop or encourage management plans to enhance and restore these areas,

including consideration of ways that the system will change with rising sea level. CDPs for dune management plans may need to include periodic reviews so the permitted plans can be updated to address increased erosion from sea level rise, and the need for increased sand retention and replenishment.

Figure 20. Photo depicting dune restoration at Surfer's Point, Ventura. (*Photograph courtesy of Surfrider Foundation*)

A.19c **Regional Sediment Management (RSM) programs**: Develop a Regional Sediment Management (RSM) program including strategies designed to allow the use of natural processes to solve engineering problems. To be most effective, RSM programs include the entire watershed, account for effects of human activities on sediment, protect and enhance coastal ecosystems, and maintain safe access to beaches for recreational purposes. LCPs can support development of an RSM program and its implementation, and the program should be periodically updated to address on-going changes from sea level rise. Natural boundaries for RSM may overlap within several LCPs, so regional cooperation may be needed for best implementation. Individual actions such as a beach nourishment project would be accomplished through a CDP. Many coastal RSM programs have already been developed and can be used as a resource. See the *Coastal Sediment Management Workgroup* website (and Appendix C) for more information.

A.19d **Maintenance or restoration of natural sand supply**: Adjustment of the sediment supply has been one of the ways natural systems have accommodated

changes from sea level. Maintenance or restoration of sediment involves identifying natural sediment supplies and removing and/or modifying existing structures or actions that impair natural sand supply, such as dams or sand mining. LCPs could include policies and implementing standards that support nature-based responses to sea level rise by maintaining and restoring natural sand supply. Where applicable, develop policies and standards to prohibit sand mining, regulate sand replenishment, and promote removal of dams or the by-passing of sand around dams. Plans should take into consideration changes in sand supply due to sea level rise and may identify and designate high priority areas for restoring natural processes. These actions and policies can also be implemented through a Regional Sediment Management (RSM) program.

A.19e **Beneficial reuse of sediment through dredging management**: Dredging involves the removal of sediment from harbor areas to facilitate boat and ship traffic or from wetland areas for restoration. Dredging management actions and plans may need to be updated to account for elevated water levels. Policies can be developed with an LCP and/or carried out through a CDP to facilitate delivery of clean sediment extracted from dredging to nearby beaches or wetland areas where needed. Beneficial reuse of sediment in this way can be coordinated through a Regional Sediment Management (RSM) program and/or through coordination with other jurisdictions.

Goal: Allow bluff and shoreline protective devices only to protect existing endangered structures

A.20 Use hard protection only if allowable and if no feasible less damaging alternative exists: "Hard" coastal protection is a broad term for most engineered features such as seawalls, revetments, cave fills, and bulkheads that block the landward retreat of the shoreline. In some cases, caissons and pilings may also be considered hard shoreline protective devices. Due to adverse effects on shoreline sand supply and beach area available for public use, such protective devices should be avoided when feasible. Under current law, shoreline protection for existing structures in danger from erosion may be allowed if coastal resource impacts are avoided or minimized and fully mitigated where unavoidable.

A.20a **Retention of existing shoreline protection**: On intensely developed, urbanized shorelines, if the removal of armoring would put existing development at risk and not otherwise result in significant protection or enhancement of coastal resources, it may be appropriate to allow properly designed shoreline armoring to remain for the foreseeable future, subject to conditions that provide for potential future removal in coordination with surrounding development. However, the proper short term responses, longer term adaptation measures, and mitigation of on-going resource impacts should be determined through updated context-specific LCP planning and consideration of the existing rights and responsibilities of development in the area (see strategies A.21 – A.25).

A.21 Require monitoring of the structure: Require periodic monitoring of the shoreline protective device to examine for structural damage, excessive scour, or other impacts from coastal hazards and sea level rise. Ensure that the structures remain within the initial footprint and that they retain functional stability.

A.22 Conditional approval of shoreline protective device: Use LCP regulations and permit conditions to require monitoring of impacts to shoreline processes and beach width both at the project site and the broader area and/or littoral cell as feasible, and provide for such actions as removal or modification of armoring in the future if it is no longer needed for protection or if site conditions change.

A.22a **Limit the authorization of shoreline protective devices to the development being protected:** Use LCP regulations and CDP conditions to require permits for bluff and shoreline protective devices to expire when the currently existing structure requiring protection is redeveloped, is no longer present, or no longer requires a protective device, whichever occurs first. Prior to expiration of the permit, the property owner should apply for a Coastal Development Permit to remove the protective device, or to modify or retain it if removal is not feasible at that time.

A.22b **Require assessment of impacts from existing pre-Coastal Act or permitted shoreline armoring:** Use LCP regulations and permit conditions to specify that expansion and/or alteration of a pre-Coastal Act or legally permitted bluff or shoreline protective device requires a new CDP and the review should include an assessment of changes to geologic site and beach conditions including but not limited to, changes in beach width relative to sea level rise, implementation of any long-term, large scale sand replenishment or shoreline restoration programs, and any ongoing impacts to public access and recreation from the existing device.

A.22c **Reassess impacts and need for existing armoring over time:** Use LCP regulations and CDPs to provide for reassessment of the impacts from protective devices at specific trigger points, including when substantial improvement or redevelopment of the structure requiring protection is proposed, or when existing armoring is being modified or expanded. Reassessment should consider the effect any significant improvement to a structure requiring protection will have on the length of time the protective device will remain, and if the existing armoring is still required, acknowledge that it is authorized to protect the existing structure only. The CDP review should assess existing site conditions and evaluate options to modify, replace, or remove the existing device in a manner that would eliminate or mitigate any identified impacts that may be occurring on public access and recreation, scenic views, sand supply, and other coastal resources, if feasible.

A.23 Require mitigation for impacts of shoreline protective devices: For unavoidable public resource impacts from shoreline structures permitted under the Coastal Act, require mitigation of resource impacts over the life of the structure as a condition of approval for the development permit. For example, require landowners to pay mitigation fees and/or complete other mitigation actions for the loss of sandy beach and other

adverse impacts on public access and recreation due to shoreline protection devices. Importantly, mitigation measures should be planned in such a way that sea level rise will not impair their efficacy over time. Other mitigation measures could include acquisition of other shoreline property for public recreational purposes, construction of public access and recreational improvements along the shoreline, and/or easements to protect lateral access along the shoreline in areas where seawalls eliminate sandy beach.

A.23a **Reassess mitigation over time as necessary:** Impacts of shoreline structures, including to shoreline and sand supply, public access and recreation, ecosystem values, and other relevant coastal resources, should be fully mitigated. Where reassessment of an approved structure is authorized, phasing of necessary mitigation may be appropriate.

A.24 Limit retention of existing shore protection: On lots with existing pre-Coastal Act or permitted armoring, consider requiring a waiver of rights to retain such protection for any structures other than the structure that existed at the time the armoring was constructed or permitted.

A.25 Removal of shoreline protection structures: The removal of shoreline protection structures can open beach or wetland areas to natural processes and provide for natural responses to sea level rise. LCPs can specify priority areas where shoreline protection structures should be removed if they are no longer needed or in a state of great disrepair, including areas where structures threaten the survival of wetlands and other habitats, beaches, trails, and other recreational areas. Once these priority areas have been identified, assessment of potential re-siting of structures and removal of armoring could be required by a CDP as redevelopment occurs.

Figure 21. Photo depicting removal of shoreline protective structure. Removal of rock revetment restores access and allows natural bluff erosion at the Ritz Carlton in Half Moon Bay. (*Source:* California Coastal Records Project)

A.25a **Remove shoreline protective structures located on public lands:** Over time, sea level rise will cause the public trust boundary to move inland. If the structures

as originally approved were located on uplands but that land becomes subject to the public trust in the future, the State Lands Commission or any local government or other entity acting as trustee for public trust lands could require the structures to be removed. The Commission or local governments could approve permit conditions to ensure permittees obtain authorization to retain or remove structures if they ever become located on public trust lands. Removal might also be accomplished through non-regulatory means such as offering incentives for removal to property owners or by incorporating removal of public structures into Capital Improvement Plans.

Goal: Require special considerations for critical infrastructure and facilities

A.26 **Plan ahead to preserve function of critical facilities**: Addressing sea level rise impacts to critical facilities and infrastructure will likely be more complex than for other resources and may require greater amounts of planning time, impacts analyses, public input, and funding. To address these complexities, establish measures that ensure continued function of critical infrastructure, or the basic facilities, service, networks, and systems needed for the functioning of a community. Programs and measures within an LCP could include identification of critical infrastructure that is vulnerable to SLR hazards, establishment of a plan for managed relocation of at-risk facilities, and/or other measures to ensure functional continuity of the critical services provided by infrastructure at risk from sea level rise and extreme storms. Repair and maintenance, elevation or spot-repair of key components, or fortification of structures where consistent with the Coastal Act may be implemented through CDPs.

A.26a **Develop or update a long-term public works plan for critical facilities to address sea level rise**: Develop a long-term management plan to address the complexities of planning for sea level rise that incorporates any potential maintenance, relocation, or retrofits and structural changes to critical facilities to accommodate changes in sea level, and obtain Coastal Commission certification.

A.27 **Apply high sea level rise projections for siting and design of critical facilities:** Given the planning complexities, high costs, and potential impacts resulting from damage, there is reason to be particularly cautious when planning and designing new critical facilities and/or retrofitting existing facilities. Ensure that critical facilities are designed to function even if the highest projected amounts of sea level rise occur and that sites with hazardous materials are protected from worst-case scenario sea level rise impacts.

A.27a **Design coastal-dependent infrastructure to accommodate worst case scenario sea level rise**: Include policies that would require proposals and/or expansion plans to address sea level rise for coastal dependent infrastructure that must necessarily be sited in potentially hazardous areas, such as industrial, energy, and port facilities. Such facilities should be designed to withstand worst case future impacts while minimizing risks to other coastal resources through initial siting, design, and/or inclusion of features that will allow for future adaptation.

A.28 Site and design wastewater disposal systems to avoid risks from sea level rise: Wastewater treatment and disposal systems are particularly challenging in that they are often located in areas that will be impacted by sea level rise. Ensure that these systems are not adversely affected by the impacts of sea level rise over the full life of the structure and ensure that damage to these facilities would not result in impacts to water quality or other coastal resources. Avoid locating new facilities in hazardous areas if possible. If complete avoidance is not possible, minimize elements of the system that are in hazardous areas (for example, locate the main facility on higher ground and only place pump stations in potentially hazardous areas), and design any facilities in hazardous areas to withstand worst-case scenario sea level rise impacts.

Goal: Protect transportation infrastructure

A.29 Identify priorities for adaptation planning and response: Carry out vulnerability analyses to identify chronic problem areas that are highly subject to erosion, wave impacts, flooding, or other coastal hazards or that maybe become so in the near future. Coordinate with Caltrans and local public works/transportation agencies to address high priority areas and increase monitoring efforts of chronic problem areas.

A.30 Add policies to address impacts to transportation routes: If transportation facilities are at risk from sea level rise, coordinate with Caltrans and local public works/transportation agencies to establish new alternative transportation routes or a plan to ensure continued alternative transportation and parking is available that allows for continued access to beaches and other recreation areas.

A.30a **Integrate LCP/land use planning processes with transportation planning processes:** Updates and changes to LCPs and other land use planning efforts should be jointly planned, evaluated, and implemented with Coordinated System Management Plans, Regional Transportation Plans, and other transportation planning efforts to ensure that long-term land use and access goals and needs are aligned.

A.31 Allow for phased implementation of realignment and relocation projects: In some cases it may be necessary to make incremental changes in transportation networks so that access to and along the coast can be maintained while also addressing coastal hazards over the long-term. For example, a phased approach may allow for interim shoreline protection to maintain an existing road alignment while future realignment plans are evaluated and pursued. Such phased approaches should be coordinated with Caltrans and local public works/transportation agencies and aligned with long-term LCP planning and adaptation goals. Individual projects will be implemented through CDPs.

Figure 22. Photo depicting planned retreat for major public infrastructure. The Piedras Blancas Highway 1 Realignment will move nearly 3 miles (5km) of Highway 1 500 ft (152 m) inland. (*Source:* California Coastal Records Project)

A.32 Plan and design transportation systems to accommodate anticipated sea level rise impacts: Ensure that transportation networks are designed to function even if the highest projected sea level rise amounts occur. Efforts to realign, retrofit, and/or protect infrastructure should be coordinated with Caltrans, local public works/transportation agencies, and LCP planning efforts, and individual projects will be implemented through CDPs.

A.32a **Retrofit existing transportation infrastructure as necessary:** In instances where relocation is not an option, repair damage and/or retrofit existing structures to better withstand sea level rise impacts. For example, use stronger materials, elevate bridges or sections of roadways, and build larger or additional drainage systems to address flooding concerns.

A.32b **Build redundancy into the system:** Provide alternate routes, as possible, to allow for access to and along the coast in instances in which sections of roadways may become temporarily impassible as a result of coastal hazards. Ensure that alternate route information is provided to residents and visitors to coastal areas.

A.33 Incorporate sea level rise considerations into Port Master Plans and other port activities: Ensure that ports and related infrastructure are designed to function given anticipated sea level rise. In some cases, this may mean initially designing structures to accommodate projected sea level rise impacts. Other options may include planning for and ensuring capacity for future adaptive actions.

A.33a **Retrofit existing port infrastructure as necessary**: Given the coastal-dependent nature of many port structures, it may not be feasible to site or relocate development to avoid hazards. In these instances it may be more appropriate to include efforts to accommodate and withstand sea level rise during actions to

repair or retrofit existing structures. Options may include using more robust designs or materials or elevating structures.

A.33b **Minimize resource impacts that may result from future use of shoreline protective structures**: If existing, coastal-dependent port structures require shoreline protective structures, minimize resource impacts as feasible and consistent with Chapter 3 and/or Chapter 8 of the Coastal Act, as applicable, by encouraging inland expansion of protective devices rather than further fill of coastal waters.

A.33c **Ensure that linkages to overland transportation networks are able to adapt to sea level rise impacts**: Coordinate with relevant stakeholders to ensure that linkages between port infrastructure and overland transportation networks will be resilient to future sea level rise impacts.

A.33d **Ensure that lessees and other parties understand sea level rise risks and vulnerabilities**: Coordinate with lessees and other stakeholders to ensure that they understand the risks associated with development in hazard areas as well as the responsibilities that come with such development.

B. Public Access and Recreation

One of the highest priorities in the Coastal Act is the mandate to maximize public access and recreational opportunities to and along the coast. The main goals and Coastal Act policies (Sections 30210, 30220, 30221, 30213) that relate to public access and recreation are to:

- Maximize public access and recreational use by protecting beaches and other coastal areas suitable for such use
- Protect lower cost visitor and recreational facilities and accessways

Chapter 3 of the Guidance covers the impacts to public access and recreation that might result from sea level rise or the interaction of sea level rise with development patterns. Certified LCPs should already have policies and standards to assure that existing public access and visitor serving amenities are protected and that maximum public access is both planned for and provided with new development when warranted. However, LCP policies and standards may need to be updated to consider sea level rise hazards. Adaptation options have been developed to support the access goals of the Coastal Act through both LCP policies and CDP conditions, and the following strategies cover a range of options for addressing the identified goals of the Coastal Act.

Goal: Maximize public access and recreational use by protecting beaches and other coastal areas

B.1 **Incorporate sea level rise into a comprehensive beach management strategy**: Update or develop a new comprehensive beach management strategy to address loss of beach areas, including loss of lateral access, or changes in beach management due to sea level rise. Establish a program to minimize loss of beach area through, as may be appropriate, a beach nourishment program; restoring sand and sediment supply to the littoral cell; removal, adjustments, or maintenance to shoreline protection structures; use of man-made structures such as terminal groins or artificial reefs to retain sediment; or other actions.

B.1a **Develop a sediment management and sand replenishment strategy**: Identify natural sediment supplies and remove and/or modify existing structures or actions that impair natural sand supply, such as dams or sand mining. LCPs could include policies and implementing standards that support nature-based responses to sea level rise by maintaining and restoring natural sand supply. Where applicable, develop policies and standards to prohibit sand mining, regulate sand replenishment, and promote removal of dams or the by-passing of sand around dams. Plans should take into consideration changes in sand supply due to sea level rise. These actions and policies can also be implemented through a Regional Sediment Management (RSM) program.

B.2 **Plan ahead to replace loss of access and recreation areas:** Identify replacement opportunities or otherwise plan ahead for how to replace recreation areas and accessways that will be lost due to inundation or damage associated with sea level rise. An LCP could designate and zone lands for this through, for example, a phased overlay or other regulatory measures that ensure that access and recreational areas are available in the future. Local governments may choose to provide additional incentives to encourage creation of new recreation areas or opportunities. Such incentives could include grant for protection new recreation areas or tax breaks for recreation related businesses.

B.2a **Protect existing open space adjacent to the coast**: Plan for future coastal recreational space and parkland by protecting open space adjacent to coastal habitats so that beaches and other habitats can migrate or so that there is open space available as parkland or other areas are lost.

B.2b **Plan for removal of structures that limit inland migration of beaches**: Seawalls and other development adjacent to beaches and other coastal habitats will impede the ability of these habitats to migrate inland and will therefore result in the inundation and eventual loss of these areas. Consideration should be given to removing and relocating these structures to ensure that beaches and other habitats are able to persist over time. Additional detail on removal of structures can be found above in the "Coastal Development and Hazards" section of this chapter.

Goal: Protect lower cost visitor and recreational facilities and accessways

B.3 **Site and design access sites and facilities to minimize impacts**: Add policies that require public access sites, segments of the CCT, and recreation and visitor-serving facilities to be sited and designed to avoid impacts from sea level rise, while maximizing public access and recreation opportunities. Examples of siting and design standards for development can be found in section A. Where facilities can be safely sited for the near term but future impacts are likely, require an adaptive management plan detailing steps for maintenance, retrofitting, and/or relocation.

B.3a **Require mitigation of any unavoidable impacts**: For unavoidable impacts to public access or recreation from shoreline armoring or other development, require mitigation of impacts through the addition of new public access, recreation opportunities, visitor-serving accommodations, or Coastal Trail segments, or payment of fees to fund such improvements. Importantly, mitigation measures should be planned in such a way that, if possible, sea level rise will not impair their efficacy over time.

B.4 **Plan ahead to replace loss of visitor-serving and recreational facilities**: Develop a plan to replace any visitor-serving facilities that are lost due to impacts from sea level rise, maximizing continued provision of affordable options and an appropriate mix of accommodations over time. For example, an LCP could include standards to re-site existing visitor-serving and recreational facilities when they become impacted by sea

level rise and/or could identify and zone for future areas to be reserved for these functions.

B.5 **Add requirements for retrofit/relocation of public access and recreation sites at risk**: The LCP can add policies that require all new public access and recreation areas, sections of the CCT, visitor- serving accommodations, or related recreation facilities to be retrofitted or relocated if they become threatened from erosion, flooding, or inundation. For new facilities and public access sites, the CDP conditions of approval can specify how maintenance, retrofit, or relocation will take place. Policies and plans should be designed to be adaptive so that retrofits and or/relocations are implemented as sea level rise impacts occur.

B.5a **Retrofit or relocate recreation and visitor-serving facilities**: Consider options to retrofit existing recreation and visitor-serving facilities to better accommodate sea level rise impacts. Such retrofits could include use of different building materials and/or relocating facilities.

B.5b **Retrofit or relocate vertical accessways**: Consider options to retrofit existing accessways to reduce impacts from sea level rise. Such retrofits could include using different materials that can better withstand impacts, or re-orienting the layout or other features of accessways to lessen damage and other impacts. Also begin to plan for and identify triggers and options for relocating accessways over time as conditions change.

B.5c **Retrofit or relocate sections of the Coastal Trail**: Use boardwalks, bridges, and/or other design features to ensure continuity of the CCT in sections that are vulnerable to SLR hazards. Some sections may need to be relocated over time. An LCP could identify vulnerable sections of the CCT and establish a phased approach to relocate sections of the trail in such a way that is consistent with provisions of the Coastal Act and ensures that the CCT remains within sight, sound, or smell of the sea.

Goal: Foster efforts to better understand impacts of sea level rise

B.6 **Support research on impacts to recreation and public access**: Changes in sea level will affect wave conditions and sediment transport, but additional research is needed to understand how these changes will affect specific conditions for surfing and other recreation activities. While such research programs may be outside the scope of individual local jurisdictions, statements of support for the local issues that need to be addressed can help guide research agendas at the regional state or federal level. Or, such needs can serve to guide grant applications to undertake the needed projects within a jurisdiction. To the extent possible, add policies to promote research on sea level rise impacts to recreational activities like surfing or other coastal recreational uses in the LCP jurisdiction.

C. Coastal Habitats, ESHA, and Wetlands

The Coastal Act provides for the protection of both land and marine habitats. It mandates that ESHA and marine resources shall be protected against significant disruption of habitat value and shall be maintained, enhanced, and restored as feasible (Sections 30230, 30233, 30240, 30240(a), 30240(b)). The main goals and Coastal Act policies that relate to coastal habitats are to:

- Protect, enhance, and restore sensitive habitats
- Avoid significant disruption to sensitive habitats
- Avoid significant impacts to habitats from adjacent development
- Manage sediment in ways that benefit habitats

Chapter 3 of the Guidance covers the impacts to coastal habitats and resources that might result from sea level rise or the interaction of sea level rise with development patterns. Certified LCPs should already have policies and standards to ensure that ESHA, wetlands, and other coastal habitats and resources are protected to the maximum extent feasible. However, LCP policies and standards may need to be updated to consider sea level rise hazards. Adaptation options have been developed to support the habitat protection goals of the Coastal Act through both LCP policies and CDP conditions, and the following strategies cover a range of options for addressing the identified goals of the Coastal Act.

Goal: Protect, enhance, and restore sensitive habitats

C.1 **Open space preservation and conservation**: Preserve land for its ecological or recreational value. This may involve limiting or prohibiting development and any uses that conflict with ecological preservation goals. LCPs can establish transfer of development rights programs to offset reduced development potential and can develop open space management plans that evaluate and consider the impacts of sea level rise, extreme events, and other climate change impacts. LCPs can establish open space and conservation areas through land use designations and zoning, redevelopment restrictions, acquisition and easement programs, and setback and buffer requirements.

C.1a **Update policies to provide for new or restored coastal habitat**: Update policies to require new coastal habitat to be provided or for degraded areas to be restored to account for the expected loss of existing habitat that will occur when development blocks the necessary upland migration due to sea level rise. Use an adaptive management approach where applicable. Encourage policies that provide for conservation or restoration of multiple habitat types.

C.1b **Identify areas for public acquisition**: New or updated LCPs can establish a program to partner with state, federal, and non-profit organizations to acquire and protect natural resource areas for public use, including areas that could serve as

refugia for species impacted by sea level rise, or areas that could be appropriate sites for coastal habitat creation or restoration.

C.1c **Establish conservation easements or other development restrictions to protect habitat**: Establish a formalized program to identify, acquire, and manage areas appropriate for some form of conservation protection. Easements or other strategies may be used to limit or restrict development on portions of a lot parcel that are most vulnerable to SLR impacts. The program might develop standard agreements to be used for easements and identify the entities that could hold the easements. A conservation easement program could be established on a community wide basis through an LCP and implemented on a parcel by parcel basis through individual CDPs.

C.1d **Require open space protection as a component of new development located adjacent to coastal habitats**: The LCP can require permit conditions for new development in certain areas that buffers around natural resource areas be protected through a conservation easement, deed restrictions, or other comparable mechanism.

C.1e **Use Rolling Easements**: See Strategy A.15 above.

C.1f **Transfer of Development Rights programs (TDR)**: See Strategy A.5b above.

Goal: Avoid significant disruption to habitats

C.2 Use ecological buffer zones and/or increase the size of buffers: Buffer zones are intended to protect sensitive habitats from the adverse impacts of development and human disturbance. An important aspect of buffers is that they are distinct ecologically from the habitat they are designed to protect. LCPs can establish requirements for ecological buffers and provide guidance on how to establish or adjust these buffers to accommodate sea level rise. CDPs should require buffers to be designed, where applicable, to provide "habitat migration corridors" that allow sensitive habitats and species to migrate inland or upland as sea level rises.

C.2a **Consider sea level rise buffer zones**: Update buffer zone policies to allow room for coastal habitats to migrate with changes in sea level. The size of the buffer needed to allow for migration will vary depending on the individual wetland or habitat type, as well as site-specific features such as natural or artificial topography and existing development. For instance, in flat areas, a larger buffer may be needed, but in steep areas, a smaller buffer may be acceptable.

C.3 Avoid impacts to Marine Protected Areas: Recognize the importance of the State's network of marine protected areas (MPAs) in protecting the diversity and abundance of marine life. Understand that planning and permitting decisions made on land could have impacts on these areas, particularly as conditions change with sea level rise, and avoid disruptions to these habitats as feasible and applicable.

C.4 Protect specific ESHA functions: Environmentally Sensitive Habitat Areas (ESHA) are areas that are critically important for the survival of species or valuable for maintaining

biodiversity. These areas can include nursery grounds, spawning areas, or highly diverse areas. Where at risk from sea level rise, the LCP should establish measures to ensure the continued viability of the habitat areas, such as protection of migration zones, habitat corridors, and other applicable adaptation strategies, as listed below. ESHA that is not at risk from sea level rise should also be afforded special protection in the LCP to serve as refugia.

C.4a **Protect wildlife corridors, habitat linkages, and land upland of wetlands to allow habitat migration**: Preserve open areas that are adjacent to wetlands to allow for migration of these habitats as sea levels rise.

C.4b **Protect refugia areas**: Protect refugia, or areas that may be relatively unaltered by global climate change and thus can serve as a refuge for coastal species displaced from their native habitat due to sea level rise or other climate change impacts.

C.4c **Promote increased habitat connectivity to allow species movement**: Connectivity refers to the degree to which the landscape facilitates animal movement and other ecological flows. Roads, highways, median barriers, fences, walls, culverts, and other structures can inhibit movement of animals. Develop LCP policies that will enable identification of important animal movement corridors. Develop regulations to protect these corridors for present and future conditions, taking into account habitat shifts from climate change. In LCPs and through CDPs, require that new structures such as highways, medians, bridges, culverts, and other development are designed to facilitate movement of animals.

C.4d **Facilitate wetland and other habitat migration**: Reserve space for a "habitat migration corridor" or areas into which wetlands and other habitats could migrate as sea level rise induced inundation of existing wetland areas occurs. In the LCP, identify potential habitat migration corridors. These areas could be reserved for this purpose in an LCP through land acquisition, use designations, zoning buffers, setbacks, conservation easement requirements, and clustering development. LCPs should also consider developing a plan for acquisition of important habitat migration corridors.

Goal: Avoid significant impacts to habitats from adjacent development

C.5 Limit new development in areas adjacent to wetlands, ESHA, and other coastal habitats: Restrict the construction of new development in areas that are adjacent to wetlands, ESHA, and other coastal habitats in order to preserve buffers and open areas to allow for habitat migration.

C.5a **Cluster development away from coastal habitats**: Existing LCPs will likely have policies that already require clustering of development. To address sea level rise, these policies might need to be updated to include clustering development away from land where wetlands and other coastal habitats could migrate with sea level rise.

C.5b **Limit subdivisions**: Update subdivision requirements to require provision for inland migration of natural resource areas or to require lots to be configured in a way that allows such migration. Lot line adjustments may sometimes be appropriate if they facilitate locating physical development further away from hazards or sensitive resources.

Figure 23. Photo depicting the preservation and conservation of open space along an urban-rural boundary. North end of Pismo Beach from 1972 (*left*) to 2002 (*right*). (*Source:* California Coastal Records Project)

Goal: Manage sediment in ways that benefit habitats

C.6 **Identify opportunities for Regional Sediment Management**: Sediment supplies will be important for the long-term sustainability of many beaches and wetland areas. Strategies to maintain or restore natural sediment supplies and to coordinate sediment removal efforts with opportunities for reuse can provide multiple benefits to coastal ecosystems. See Strategy A.19c above for more detail on RSM programs.

C.6a **Restore natural sediment sources to wetlands**: Restoration of natural hydrodynamic systems will help to ensure the ability of wetlands to persist with sea level rise by ensuring that sediment is available for wetland accretion. Such actions may include restoring natural channels in streams and waterways that have been armored or channelized. Organizing and coordinating such efforts may be accomplished through a Regional Sediment Management Plan.

C.6b **Identify opportunities for beneficial reuse of sediment to support wetland restoration**: Consider facilitating the delivery of clean, dredged sediment to areas where former wetlands have subsided or to areas where existing wetlands are or may become sediment-limited as sea levels rise.

Goal: Incorporate sea level rise into habitat management actions

C.7 **Include sea level rise in site-specific evaluations**: Update policies to require site-specific biological evaluations and field observations of coastal habitat to include an evaluation of vulnerability to sea level rise where appropriate. Such an evaluation should consider both topographic features as well as habitat and species sensitivities (for example, sensitivity to inundation and saltwater intrusion).

C.8 Incorporate sea level rise in restoration, creation, or enhancement of coastal habitats: Update policies to require site-specific biological evaluations and field observations of coastal habitat to include an evaluation of vulnerability to sea level rise. Such an evaluation should consider both topographic features as well as habitat and species sensitivities (for example, sensitivity to inundation and saltwater intrusion). Habitat restoration, creation, or enhancement projects should be designed to withstand impacts of sea level rise and adapt to future conditions. As applicable, the LCP should contain policies to ensure restoration and management techniques account for future changes in conditions. CDPs for restoration projects should incorporate sea level rise and provisions to ensure habitats can adapt with changing future conditions.

C.9 Update habitat management plans to address sea level rise: Add policies stating that the effects of sea level rise should be addressed in management plans for coastal habitats. For example, plans should evaluate the full range of sea level rise impacts to coastal habitats, and develop a strategy for managing coastal habitats given changing sea level rise conditions. Existing management plans may need to be updated to add new monitoring and restoration requirements to address sea level rise. The strategies listed below are examples of strategies that could be included in habitat management plans.

C.9a **Use an adaptive management approach in ecosystem management, restoration, or design**: Habitat management plans and/or other habitat projects should establish an adaptive management approach, with clearly defined triggers for adaptive actions. Such an approach would allow for and ensure that coastal habitats are able to migrate and transition with changes in sea level.

Figure 24. Photo depicting habitat protection at Salinas River State Beach. Dunes are roped off to protect Snowy Plover nesting habitat. (*Source:* California Coastal Records Project)

C.10 Pursue strategies to protect ecosystem function under a range of future sea level rise or climate change scenarios: The LCP and/or habitat management plans can recommend coastal habitat management strategies that strive to protect ecosystem function in the future. Strategies include protecting a wide range of ecosystem types, protecting refugia, protecting wildlife and habitat corridors, and establishing methods to monitor ecosystem change over time.

C.10a **Update monitoring requirements for coastal habitats**: As part of the LCP and/or habitat management plans, consider establishing a monitoring protocol and requirements for evaluating sea level rise impacts to coastal habitats over time. Such a protocol would also help identify triggers at which additional adaptation options are necessary.

D. Agricultural Resources

Agriculture is a priority use within the Coastal Act, which mandates that the maximum amount of prime agricultural land shall be protected and maintained (Sections 30231, 30241, 30242). The main goals and Coastal Act policies that relate to agriculture are to:

- Protect the maximum amount of prime agricultural land
- Limit conversion of lands suitable for agriculture to non-agricultural uses
- Minimize impacts to water quality that could result from agricultural practices
- Promote water conservation efforts

Chapter 3 of the Guidance describes the impacts to agricultural resources that may result from sea level rise. Certified LCPs should already have policies and standards to ensure that agricultural resources are protected to the maximum extent feasible. However, LCP policies and standards may need to be updated to address sea level rise hazards. Adaptation options have been developed to support the agricultural protection goals of the Coastal Act through both LCP policies and CDP conditions, and the following strategies cover a range of options for addressing the identified goals of the Coastal Act.

Goal: Protect the maximum amount of prime agricultural land

D.1 **Identify and designate areas suitable for agricultural production to replace agricultural production areas that could be lost to sea level rise:** Identify any non-sensitive open or developed areas, both within and outside of the Coastal Zone, which could potentially be used to replace agricultural land that is lost to sea level rise. Update LCP designations and/or policies to protect these identified areas for agricultural production and, as applicable, to provide for their conversion to agricultural use. Encourage and support regional coordination as feasible and applicable.

D.1a **Establish SLR-specific agricultural protection program:** Establish a formal program to identify, acquire, incentivize, and manage areas appropriate for new/renewed agricultural use and/or for protection of current and/or future agricultural uses. Such program should target key areas and properties where agricultural conversion threats are highest, and should dovetail with existing agricultural protection programs. Easements and other legal restrictions may be used as part of such program to help limit or restrict development in areas where agricultural land and production are most vulnerable to sea level rise impacts. The program might develop standard language and/or legal documents that can be used for easements or other property restrictions. The program should be flexible enough to be able to be implemented on both a large scale (*e.g.*, though LCP policies and programs) as well as on a smaller scale (*e.g.*, through the CDP process).

D.2 **Protection, maintenance, and adaptation of dikes and levees**: Repairing and maintaining existing flood barriers such as dikes and levees may be a cost-effective way to continue to protect agricultural areas. While some repair and maintenance activities are exempt from the need for a CDP, the repair and maintenance exemption does not apply to repair and maintenance work that is located within an ESHA, within any sand area, within 50 feet of the edge of a coastal bluff or ESHA, or within 20 feet of coastal waters. LCPs could identify opportunities for these kinds of actions and ensure that they are appropriately permitted, with consideration to the environmental protection and restoration goals of the Coastal Act. While landowners have the right to repair and maintain existing legal levees in their current configurations, the Commission and local governments administering LCPs have the authority to regulate, via the CDP process, the proposed methods of repair and maintenance. To raise, reconfigure, enlarge, or widen levees is not repair and maintenance and requires a Coastal Development Permit. Such activities may not be consistent with the Coastal Act or certified LCP, such as in cases involving wetland fill impacts. However, where there are opportunities to restore marine resources and the biological productivity of wetlands and estuaries, it may be possible to permit a dike/levee reconstruction project that provides for substantial restoration.

Goal: Limit conversion of lands suitable for agriculture to non-agricultural uses

D.3 **Limit conversion of agricultural land to other developed land uses**: Develop policies to assure maximum environmentally feasible protection of rural agricultural land, open space, and other coastal resources, including areas that may be considered non-prime agricultural land at this time. Anticipate areas that could become more difficult to farm and identify strategies to avoid or mitigate the potential impacts.

Goal: Minimize impacts to water quality that could result from agricultural practices

D.4 **Include sea level rise in water quality protection policies**: Where needed, coordinate with regional water quality control boards to add policies to reduce water pollution from runoff should agricultural lands become flooded or inundated due to sea level rise.

D.4a **Minimize water quality impacts from flooding of agricultural lands**: Agricultural practices that are designed to minimize water quality impacts, such as those designed to minimize runoff, may need to be updated or enhanced to ensure water quality protection if sea level rise results in more frequent flooding of agricultural lands.

D.4b **Add policies to address saltwater intrusion**: Add policies to protect water supply for priority coastal agriculture, including policies to address saltwater intrusion, such as limits on groundwater withdrawal or diversification of water supplies. Strategies to pump freshwater and/or highly treated wastewater into aquifers to reduce saltwater intrusion should be minimized in areas with limited freshwater resources.

Goal: Promote water conservation efforts

D.5 **Maximize water conservation to protect priority agricultural water supplies**: Saltwater intrusion and other climate change impacts may result in reduced water availability. LCP policies should be updated to establish or enhance standards related to water conservation and/or to identify opportunities for water recycling, dual plumbing systems, and the like. For more information on options such as relocating wells and reducing pumping in sensitive aquifers, see the following section on Water Quality and Water Control Management.

D.6 **Identify alternate water sources for agriculture**: Establish a program to identify alternate water sources for agriculture.

E. Water Quality and Supply

The main water quality protection policy of the Coastal Act requires minimizing the adverse effects of wastewater discharges, runoff, and groundwater depletion in order to protect the biological productivity and quality of coastal waters, as described in Section 30231. The main goals related to water quality include:

- Control runoff and stormwater pollution
- Minimize adverse effects of wastewater discharges and entrainment
- Prevent depletion of groundwater supplies from saltwater intrusion
- Improve long-term water quality through research

Chapter 3 of the Guidance covers the impacts to coastal waters from increased runoff, wastewater discharge and saltwater intrusion into groundwater sources from sea level rise. Adaptation options have been developed to limit the amount of pollutants that enter coastal waters through runoff or discharges.

Goal: Control runoff and stormwater pollution

E.1 **Update water quality Best Management Practices (BMPs)**: Evaluate and update BMPs to account for changes in water quality and supply issues due to sea level rise, as applicable. Updates could include practices to provide greater infiltration/inflow of rainwater, increased stormwater capture and/or water recycling programs, the use of low impact development, improved maintenance procedures for public sewer mains, policies to address impaired private sewer laterals, and other proactive measures.

E.2 **Include sea level rise in stormwater management plans and actions**: Control the amount of pollutants, sediments, and nutrients entering water bodies through precipitation-generated runoff. LCPs should include sea level rise and extreme storms in stormwater management plans and actions. CDPs for stormwater infrastructure should consider sea level rise.

E.2a **Increase capacity of stormwater infrastructure**: Actions to reduce impacts from higher water levels could include widening drainage ditches, improving carrying and storage capacity of tidally-influenced streams, installing larger pipes and culverts, adding pumps, converting culverts to bridges, creating retention and detention basins, and developing contingency plans for extreme events. Encouraging and supporting these types of efforts upstream may also be important.

E.2b **Use green stormwater infrastructure to the maximum extent feasible**: Employ natural, on-site drainage strategies to minimize the amount of stormwater that flows into pipes or conveyance systems. These strategies include low impact development, green roofs, permeable pavements, bioretention (*e.g.*, vegetated

swales, rain gardens) and cisterns. LCPs can include policies that require green infrastructure be used whenever possible *in lieu* of hard structures. Incorporate sea level rise and extreme storms into the design.

E.2c **Retrofit existing development with inadequate stormwater infrastructure**: Identify and prioritize development in low-lying or other at-risk areas with inadequate stormwater infrastructure and take steps to retrofit these systems to better accommodate sea level rise driven changes. Retrofits should incorporate the green infrastructure options detailed in strategy E.2c above as applicable.

Goal: Minimize adverse effects of wastewater discharges and entrainment

E.3 Add policies to address water quality risks from wastewater treatment plants, septic systems, and ocean outfalls: Consider establishing a program to retrofit, relocate, or eliminate ocean outfalls and other wastewater infrastructure deemed at risk. Alternatives include modifications to outfall lines, the use of green infrastructure, and redesign of waste and stormwater systems.

E.3a **Update siting and design policies**: Add policies to ensure that new ocean outfalls, wastewater treatment facilities, and other facilities that could negatively impact water quality if flooded or inundated, are sited and designed to minimize impacts from sea level rise. Avoid construction of new stormwater outfalls and direct stormwater to existing facilities with appropriate treatment and filtration where feasible. Where new outfalls cannot be avoided, plan, site, and design stormwater outfalls to minimize adverse impacts on coastal resources, including consolidation of existing and new outfalls where appropriate. Consolidate new and existing outfalls where appropriate.

E.3b **Retrofit, relocate, or eliminate outfalls deemed "at risk"**: An ocean outfall is a pipeline or tunnel that discharges municipal or industrial wastewater, stormwater, combined sewer overflows, cooling water, or brine effluents from desalination plants to the sea. LCPs should identify areas where sea level rise could affect flow of wastewater from outfalls and lead to backup and inland flooding, and plans should be made to retrofit, relocate, or eliminate these outfalls to prevent damage and impacts to water quality. Additionally, CDPs for new ocean outfalls should consider sea level rise in the design.

E.3c **Reduce or find alternatives for septic systems in hazardous areas**: Flooding, inundation, and changing groundwater dynamics may result in impacts to septic systems, which rely on leach fields for dispersal of wastewater, that could cause water quality impairments. Options to reduce the potential for these impacts by redesigning or eliminating septic systems in hazardous areas should be identified. New development that will rely on septic systems should be limited in hazardous areas.

Goal: Prevent depletion of groundwater supplies from saltwater intrusion

E.4 **Groundwater Management**: Plan and coordinate monitoring, operation, and administration of a groundwater basin or portion of a groundwater basin with the goal of fostering long-term sustainability of the resource. The LCP can add policies that specify limits or establish other standards for the use of groundwater and sensitive aquifers. These policies should be made in accordance with other regional water planning efforts, such as Integrated Regional Water Plans as well as relevant state water policies. CDPs involving the use of groundwater should address groundwater management issues.

E.4a **Add policies to address saltwater intrusion into aquifers**: Consider adding policies that establish a long-term strategy for addressing saltwater intrusion in aquifers, including limiting development that would use sensitive aquifers as applicable. For some areas of the state, additional information is needed on the site-specific impacts of sea level rise on aquifers. For these areas, the LCP could identify the local information needs and promote the establishment of a research program to increase understanding of the vulnerability of coastal aquifers.

E.4b **Limit groundwater extraction from shallow aquifers**: Groundwater extraction from shallow aquifers can increase susceptibility to saltwater intrusion. Regulating development to limit or prevent extraction and avoid overdraft from vulnerable aquifers can reduce the impacts of saltwater intrusion and preserve fresh groundwater supplies. LCPs or CDPs can add restrictions to the use of aquifers susceptible to saltwater intrusion and can encourage measures to recharge shallow aquifers that are depleted.

E.4c **Relocate wells and water intake facilities**: Identify opportunities to relocate wells and water intake facilities away from hazards and/or areas where saltwater intrusion may be a problem.

E.4d **Restrict development of new wells in sensitive areas**: Require new water wells to be sited away from areas where saltwater intrusion could occur.

E.4e **Limit development that relies on vulnerable water supplies**: Limit or restrict new development in areas that are dependent on water supplies that are or will become susceptible to saltwater intrusion.

E.4f **Ensure adequate long term water supplies:** When siting and designing new development, ensure that adequate and sustainable water sources are available for the lifetime of the development and suitable for the intended use of the development, considering potential impacts of sea level rise and saltwater intrusion upon groundwater supplies.

Goal: Improve long-term water quality through research

E.5 Identify research and monitoring needs to more precisely understand local issues: Research programs may be established to analyze the particular local challenges related to water quality and supply as a result of sea level rise. Opportunities for innovative solutions to these challenges should be identified.

E.5a **Clearly define areas at risk**: The LCP should include an updated inventory of potential pollutant sources due to sea level rise, including toxic waste sites, ocean outfalls and wastewater treatment facilities at risk of inundation, as well as aquifers and wells at risk of saltwater intrusion. Policies may also be added to prioritize low-lying contaminated sites for remediation and restoration.

F. Archaeological and Paleontological Resources

The Coastal Act provides for the protection of archaeological and paleontological resources, stating in Section 30244 that:

> "Where development would adversely impact archaeological or paleontological resources as identified by the State Historic Preservation Officer, reasonable mitigation measures shall be required."

Chapter 3 of the Guidance discusses the impacts to archaeological and paleontological resources that might result from sea level rise. Certified LCPs should already have policies and standards to ensure that these resources are protected to the maximum extent feasible, however, such policies and standards may need to be updated to consider sea level rise hazards. The following strategies cover a range of options for addressing the identified goals of the Coastal Act.

Goal: Protect archaeological and paleontological resources

F.1 **Add policies to protect archeological and paleontological resources from sea level rise:** Add policies to require site-specific evaluation of potential sea level rise impacts to archeological and paleontological resources on a development site. The LCP can also add requirements that a monitoring program and plan be established as a condition of approval for development located on a site with artifacts vulnerable to sea level rise. Adaptation or protection strategies used may depend on the significance of the archaeological resources in question.

F.1a **Consult with relevant tribes for guidance:** If resources are at risk, the appropriate entity or Native American tribe(s) should be contacted to develop a coordinated management plan for artifacts. See, for example, the *California Natural Resources Agency Final Tribal Consultation Policy* for additional guidance.

F.1b **Coordinate with the State Historic Preservation Officer (SHPO):** In line with the provisions of the Coastal Act, work with the State Historic Preservation Officer to identify actions to protect archaeological and paleontological resources.

G. Scenic and Visual Resources

The scenic value of the coast is a resource of public importance. As noted in Section 30251 of the Coastal Act, development shall be sited and designed to:

> "Protect views to and along the ocean and scenic coastal areas, to minimize the alteration of natural landforms…and to restore and enhance visual quality in visually degraded areas."

As stated in Chapter 3 of the Guidance, some options to address rising sea levels, such as elevating structures or utilizing seawalls or bluff retention devices, have the potential to alter or degrade the visual character of an area. Certified LCPs should already have policies and standards to ensure scenic and visual resources are protected to the maximum extent feasible, but these may need to be updated to consider sea level rise hazards. Coastal regions with scenic overlays or designated scenic corridors, or those areas designated as scenic in the California Coastal Preservation and Recreation Plan in particular should pay close attention to actions that could be used to minimize risks to development. The following adaptation options address some of the methods for protecting the scenic qualities of the coast.

Goal: Protect views to and along the ocean and scenic coastal areas

G.1 **Establish design standards to protect visual resources**: Update and/or add design standards to ensure that adaptation measures protect visual resources while minimizing hazards. Adaptation strategies such as shoreline armoring or elevation techniques should be designed such that the visuals are subordinate to, and in character with, the surrounding visual resources of an area.

G.1a **Establish standards for the use of caissons or other means of elevating structures:** Ensure that the use of caissons or other elevation techniques do not result in negative visual impacts. Develop policies regarding where elevation of structures may be allowable, and establish standards guiding the use of these techniques. Ensure that the appearance of caissons will not detract from the scenic character of an area if or when they become visible as a result of erosion or other processes.

G.1b **Maintain height limitations in scenic areas**: Avoid modifications to height limits in scenic areas and provide for options to modify roof-lines or elevate the lowest flood elevation for flood protection in a manner that is consistent with scenic character. In some cases it may be appropriate to update height limitations to allow for elevation in response to sea level rise hazards. However, such decisions will require trade-offs and will need to strike a balance in terms of adapting to sea level rise and protecting visual resources and community character in line with the requirements of the Coastal Act.

G.1c **Develop or redevelop property to be safe from hazards without impairing scenic resources**: Emphasize the use of adaptation strategies that will not impact visual resources. Such strategies may include short-term retrofits with plans for longer term relocation or removal.

G.1d **Establish new scenic communities**: Designate areas with significant visual resources that could be negatively impacted by adaptation responses (*e.g.*, due to seawalls or "spider" homes) as scenic communities with special protections. Establish standards in LCPs to specifically protect visual resources in these areas.

Figure 25. Photo depicting protection of visual resources and public access. A seawall visually blends in with the natural bluff while surfing access is also provided at Pleasure Point, Santa Cruz (2013). (*Source:* California Coastal Records Project)

Chapter 8

Legal Context of Adaptation Planning

Land use law is dynamic and must be interpreted and applied based on case-specific factors at the time of decision. Nonetheless, sea level rise and adaptation planning raise a number of important legal issues that coastal managers should consider as they develop and apply adaptation strategies.

This section includes discussion of the legal contexts for addressing:

- Seawalls and other shoreline protective devices
- The public trust boundary
- Potential private property takings issues

SEAWALLS AND OTHER SHORELINE PROTECTIVE DEVICES

Section 30235 of the Coastal Act provides that seawalls and other forms of construction that alter natural shoreline processes "shall be permitted when required to serve coastal-dependent uses or to protect existing structures or public beaches in danger from erosion, and when designed to eliminate or mitigate adverse impacts on local shoreline sand supply." Despite other Coastal Act provisions that could often serve as the basis for denial of shoreline protective devices (for example, new development requiring shoreline protection can also conflict with Coastal Act policies requiring protection of public access and recreation, coastal waters and marine resources, natural landforms, and visual resources), the Coastal Commission has interpreted Section 30235 as a more specific overriding policy that requires the approval of Coastal Development Permits for construction intended to protect coastal-dependent uses[47] or existing structures if the other requirements of Section 30235 are also satisfied.[48] The Commission thus will generally permit a shoreline protective device if (1) there is an existing structure, public beach, or coastal-dependent use that is (2) in danger from erosion; and (3) the shoreline protection is both required to address the danger (the least environmentally-damaging, feasible alternative) and (4) designed to eliminate or mitigate impacts on sand supply.

In contrast to Section 30235, Coastal Act Section 30253 requires that "new development…assure stability and structural integrity, and neither create nor contribute significantly to erosion…or destruction of the site or surrounding area or in any way require the construction of protective devices that would substantially alter natural landforms along bluffs and cliffs." The Commission has long applied this policy to implement appropriate bluff-top and shoreline setbacks for new development. Such setbacks are based on an assessment of projected erosion and related hazards at the site for the life of the proposed development and help ensure that seawalls and other protective devices that could lead to adverse impacts would not be necessary in the future.

[47] Coastal-dependent uses are those that require a site on, or adjacent to, the sea to be able to function at all. (Public Resources Code, § 30101.)

[48] Some commenters argue that because shoreline armoring often conflicts with Coastal Act policies other than Section 30235, the Commission should evaluate proposed armoring under the conflict resolution provisions of the Act. (See Public Resources Code, § 30007.5, 30200(b).) Because the conflict resolution provisions require the Commission to resolve the conflict in a manner which on balance is the most protective of significant coastal resources, this approach could result in the more frequent denial of shoreline armoring, especially when it is intended to protect residential development or other uses that the Coastal Act does not identify as priority uses.

Additionally, from its earliest days, the Commission has also required that landowners "assume the risks" of developing along shoreline and coastal bluffs where risks of coastal hazards are present. Since at least the late 1990s, the Commission has approved many new developments with required deed restrictions that specifically prohibit any future construction of shoreline protection for these developments. These deed restrictions require that property owners waive any rights that may exist for a shoreline structure under Section 30235 and thus internalize the risks of building in an inherently hazardous location. This, in turn, will protect shoreline areas with natural resources or other access, recreational, or scenic value, including as required by Section 30253. If and when the approved development is threatened by erosion and becomes uninhabitable, these deed restrictions prevent the construction of a shoreline protective device and require property owners to remove the development, as well as clean up any debris that may result from erosion undermining the development.[49]

Read together, the most reasonable and straight-forward interpretation of Coastal Act Sections 30235 and 30253 is that they evince a broad legislative intent to allow shoreline protection for development that was in existence when the Coastal Act was passed, but avoid such protective structures for new development now subject to the Act. In this way, the Coastal Act's broad purpose to protect natural shoreline resources and public access and recreation would be implemented to the maximum extent when new, yet-to-be-entitled development was being considered, while shoreline development that was already entitled in 1976 would be "grandfathered" and allowed to protect itself from shoreline hazards if it otherwise met Coastal Act tests even if this resulted in adverse resource impacts. Such grandfathering of existing conditions is common when new land use and resource protection policies are put in place, and the existing development becomes "non-conforming."

Even still, in the case of Coastal Act Section 30235, existing development is only entitled to shoreline protection if it is in fact in danger, and the proposed shoreline protection is the least environmentally-damaging alternative to abate such danger. It may be that in certain circumstances existing development can be modified or feasibly relocated, or that other non-structural alternatives such as reducing blufftop irrigation or pursuing beach replenishment, may effectively address the risk to the development without the need for a shoreline protective device.

In practice, implementing Sections 30235 and 30253 has been challenging because many urban areas are made up of both developed and undeveloped lots. In addition, many developments in existence in 1976 have since been "redeveloped" through renovations, remodeling, additions, and complete demolition and rebuild. The reality of effective shoreline management is that the Coastal Act and LCPs must address and be applied to a wide variety of physical and legal circumstances that may not be addressed by a simple application of the clean Coastal Act distinction between existing development that may be entitled to shoreline protection and new development that is not. In some urban areas, for example, one may find intermingled shoreline developments that pre-date the Coastal Act, both with and without shoreline protection, post-Coastal Act developments approved by the Coastal Commission or local governments pursuant to an LCP that theoretically won't need shoreline protection (though some may have it), and

[49] This legal instrument is not an easement but it does provide for "planned retreat" into the future as a site erodes. Once a development is removed, a site may have potential for new development if it is once again set back and restricted against future shoreline protection device construction.

developments that may have pre-dated the Coastal Act but that were redeveloped pursuant to a coastal development permit. Moreover, some of the post-Coastal Act developments may have conditions that prohibit shoreline protection while adjacent properties may be eligible for or have a protective device because they pre-date the Act.

For purposes of implementing this Guidance, it is important that local governments, property owners, development applicants, and others take full advantage of available legal tools to mitigate hazards and protect resources, but to do so in way that considers the specific legal context and circumstances of LCP updates and individual development decisions in context and on a case-by-case basis. For example, although the Coastal Act does not explicitly define what qualifies as an "existing structure" for the purposes of Section 30235, how this term is interpreted in specific cases and through LCPs may be critical to the success of an adaptation strategy over the long-run.

The Commission has relatively infrequently evaluated whether structures built after 1976 should be treated as "existing" and thus entitled to shoreline protection pursuant to Section 30235. When it has, the shoreline protection being proposed to protect the structure has often also been identified as necessary to protect adjacent pre-Coastal Act structures.[50] In a few instances, however, the Commission has treated structures built after 1976 as existing structures entitled to shoreline protection even if no adjacent pre-Coastal Act structure also needed protection. Nonetheless, going forward, the Commission recommends the rebuttable presumption that structures built after 1976 pursuant to a coastal development permit are not "existing" as that term was originally intended relative to applications for shoreline protective devices, and that the details of any prior coastal development approvals should be fully understood before concluding that a development is entitled to shoreline protection under Section 30235.

As mentioned, in order to find new development consistent with Section 30253 or related LCP requirements and to limit the potential proliferation of armoring to protect newly approved structures, the Commission has long used setbacks, assumption of risk conditions and, over the last 15-20 years, generally required that applicants proposing new development in hazardous shoreline locations waive any rights under Section 30235 (or related LCP policies) to build shoreline protection for the proposed new development. Notably, no appellate decision addresses whether the term "existing structures" in this context includes only structures built prior to the Coastal Act or instead includes structures in existence at the time the Commission acts on an application for shoreline protection, or otherwise addresses the interplay between 30235 and 30253.

LCP updates are an opportunity to clarify how the distinction between existing and new development will be applied in specific areas, and some LCP's have already done so. For example, local governments have sometimes specified a date by which a structure must have been constructed in order to qualify as an "existing structure" for the purpose of evaluating whether it may be eligible for shoreline protection. In Marin County, the Local Coastal Program

[50] For example, CDP A-3-CAP-99-023-A1, *Swan and Green Valley Corporation Seawall*. In this situation, repairs to maintain a seawall fronting the pre-coastal Swan Residence could only be undertaken by encroachment onto the adjacent property, Green Valley Corporation; however, the Green Valley Corporation development had been approved with a condition to prohibit any future shore protection.

policy that implements Section 30235 specifies that existing structures are those that existed on the date the LCP was originally adopted (May 13, 1982). LCPs can also codify the prohibition on shoreline protective devices for new development, such as the following provision from the San Luis Obispo County North Coast Area Plan standard:

> ***Seawall Prohibition***. *Shoreline and bluff protection structures shall not be permitted to protect new development. All permits for development on blufftop or shoreline lots that do not have a legally established shoreline protection structure shall be conditioned to require that prior to issuance of any grading or construction permits, the property owner record a deed restriction against the property that ensures that no shoreline protection structure shall be proposed or constructed to protect the development, and which expressly waives any future right to construct such devices that may exist pursuant to Public Resources Code Section 30235 and the San Luis Obispo County certified LCP.*[51]

The distinction between existing and new development inherent in the Coastal Act is often directly raised by proposals for redevelopment as well. This Guidance thus deals directly with potential approaches for managing shoreline hazards and protecting coastal resources as shorelines are redeveloped (see Chapter 7, Strategy A.13). Most recently, the Commission approved a Land Use Plan for the City of Solana Beach that includes many policies designed to address the existing residential development pattern along the high, eroding bluffs of the City. Although further elaboration is yet to come through the City's work on the Implementation Plan, the Solana Beach LUP is a good example of an effort to pragmatically address the need to mitigate the risks to residential development, provide for some redevelopment potential while moving the line of new development inland, avoid and minimize new bluff protection and seawalls, and perhaps remove protective devices in the future to minimize impacts to natural landforms and to protect the beach for long-term public use.

Local governments and other shoreline managers should also take into account that although a public agency may not deny a Coastal Development Permit for a shoreline protective device that meets all of the tests under Section 30235 and equivalent LCP policies, this does not limit the authority of public agencies to refuse to allow construction of shoreline protective devices pursuant to some authority other than the Coastal Act. For example, if a private property owner requests permission from a public agency to build a structure on that agency's property (such as a local or State park or public beach) to protect adjacent private property, the public agency would generally have the authority as the landowner not to agree to the encroachment. Similarly, agencies that are trustees of public trust lands (such as the State Lands Commission and Port Districts) have the authority to prohibit structures that are not consistent with public trust uses and prioritized public trust needs, values, and principles. Public trust uses include maritime commerce, navigation, fishing, boating, water-oriented recreation, and environmental preservation and restoration, but do not typically include non-water dependent uses such as residential or general commercial and office uses. Thus, trustee agencies have the authority to refuse to allow, or to require removal of, shoreline armoring located on public trust lands, including if that armoring unreasonably interferes with public trust uses.

[51] Community-wide standard 15C.

Approval of a Coastal Development Permit for shoreline armoring under Section 30235 may be unavoidable in certain circumstances. Nonetheless, the construction of shoreline armoring will often cause impacts inconsistent with other Coastal Act requirements, including Section 30235's requirement that a shoreline protective device be the least-environmentally damaging, feasible alternative for addressing shoreline hazards. For example, as discussed above, Section 30253(b) prohibits *new development* from in any way requiring the construction of protective devices that would substantially alter natural landforms along bluffs and cliffs. Shoreline protective devices can also adversely affect a wide range of other coastal resources and uses that the Coastal Act protects. They often impede or degrade public access and recreation along the shoreline by occupying beach area or tidelands, by reducing shoreline sand supply, and by fixing the back of the beach, ultimately leading to the loss of the beach. Shoreline protection structures thus raise serious concerns regarding consistency with the public access and recreation policies of the Coastal Act. Such structures can fill coastal waters or tidelands and harm marine resources and biological productivity in conflict with Sections 30230, 30231, and 30233. They often degrade the scenic qualities of coastal areas and alter natural landforms in conflict with Section 30251. Finally, by halting shoreline erosion, they can prevent the inland migration of intertidal habitat, salt marshes, beaches, and other low-lying habitats that rising sea levels will inundate.

Even when an agency approves a Coastal Development Permit for shoreline armoring, the agency has the authority to impose conditions to mitigate impacts on shoreline sand supply and to minimize adverse impacts on other coastal resources. (See *Ocean Harbor House Homeowners Assn. v. California Coastal Comm.* (2008) 163 Cal.App.4th 215, 242; Public Resources Code, §30607.)[52] Any approved shoreline structure, therefore, must avoid or mitigate impacts that are inconsistent with Coastal Act policies.

Because of the wide range of adverse effects that shoreline protective devices typically have on coastal resources, this Guidance recommends avoidance of hard shoreline armoring whenever possible. This can entail denying development in hazardous locations, allowing only development that is easily removable as the shoreline erodes, or requiring new development to be set back far enough from wave runup zones or eroding bluff edges so that the development will not need shoreline armoring during its anticipated lifetime. The Commission's practice when reviewing proposed development in shoreline locations that are potentially vulnerable to shoreline erosion, wave runup, or inundation has been to require applicants to waive rights to shoreline protective devices in the future, and, more recently, to require relocation and/or removal should such development become endangered in the future. See Chapter 7: Adaptation Strategies for further details regarding alternatives to the use of hard armoring structures.

PUBLIC TRUST BOUNDARY

The State of California acquired sovereign ownership of all tidelands and submerged lands and beds of navigable waterways upon its admission to the United States in 1850. The State holds and manages these lands for the benefit of all people of the State for statewide purposes consistent with the common law Public Trust Doctrine ("public trust"). The public trust ensures that title to sovereign land is held by the State in trust for the people of the State. Public trust

[52] Indeed, as noted above, 30235 itself clarifies that even when approvable, such structures should be designed to eliminate or mitigate any adverse impacts on local shoreline sand supply.

uses include maritime commerce, navigation, fishing, boating, water-oriented recreation, visitor-serving facilities and environmental preservation and restoration. Non-water dependent uses such as residential and general office or commercial uses are generally inconsistent with public trust protections and do not qualify as public trust uses.

In coastal areas, the landward location and extent of the State's sovereign fee ownership of these public trust lands are generally defined by reference to the ordinary high water mark (Civil Code §670), as measured by the mean high tide line (*Borax Consolidated v. City of Los Angeles* (1935) 210 U.S. 10); these boundaries remain ambulatory, except where there has been fill or artificial accretion. More specifically, in areas unaffected by fill or artificial accretion, the ordinary high water mark and the mean high tide line will generally be the same. In areas where there has been fill or artificial accretion, the ordinary high water mark (and the state's public trust ownership) is generally defined as the location of the mean high tide line just prior to the fill or artificial influence. It is important to note that such boundaries may not be readily apparent from present day site inspections (*Carpenter v. City of Santa Monica* (1944) 63 C. A. 2nd 772, 787).

The mean high tide line is the intersection of the shoreline with the elevation of the average of all high tides calculated over an 18.6-year tidal epoch. This property line is referred to as "ambulatory" for two reasons: first, gradual changes to the shoreline due to factors such as variations in the height and width of sandy beaches, shoreline erosion or accretion, and uplift or subsidence of land can change the location of where the mean high tide line meets the shoreline. Second, the elevation of the mean high tide line itself changes over time and is likely to increase at an accelerating rate in the future due to sea level rise. Over time, sea level rise will continue to gradually cause the public trust boundary to move inland. Boundaries between publicly-owned waterways and adjoining private properties (referred to as *littoral* along lakes and seas and *riparian* along rivers and streams) have always been subject to the forces of nature and property boundary law reflects these realities.

Accelerating sea level rise will likely lead to more disputes regarding the location of property boundaries along the shoreline, since lands that were previously landward of the mean high tide line have become subject to the State's ownership and protections of the public trust. These disputes, in turn, will affect determinations regarding what kinds of structures and uses may be allowed or maintained in areas that, because of sea level rise, either are already seaward of the mean high tide line, are likely to become seaward of the mean high tide line in the future, or would be seaward of the mean high tide line if it were not for artificial alterations to the shoreline.

California case law does not explicitly address how shoreline structures such as seawalls that artificially fix the shoreline temporarily and prevent inland movement of the mean high tide line affect property boundaries, if at all. The Ninth Circuit Court of Appeals, however, has interpreted federal common law as allowing the owner of tidelands to bring a trespass action against a neighboring upland property owner who built a revetment that prevented the natural inland movement of the mean high tide line. The court ruled that the actual property boundary was where the mean high tide line would have been if the revetment were not there and that the owner of the tidelands could require the upland owners to remove the portions of the revetment

that were no longer located on the upland owners' properties. (*United States v. Milner* (9th Cir. 2009) 583 F.3d 1174, 1189-1190.)

POTENTIAL PRIVATE PROPERTY TAKINGS ISSUES

The United States and California constitutions prohibit public agencies from taking private property for public use without just compensation. Section 30010 of the Coastal Act similarly prohibits public agencies implementing the Coastal Act from granting or denying a permit in a manner that takes or damages private property for public use without payment of just compensation. The classic "takings" scenario arises when a public agency acquires title to private property in order to build a public facility or otherwise devote the property to public use. In 1922, however, the United States Supreme Court ruled that regulation of private property can constitute a taking even if the regulation does not involve acquisition of title to the property. As Justice Oliver Wendell Holmes stated, "while property may be regulated to a certain extent, if regulation goes too far it will be recognized as a taking," (*Pennsylvania Coal Co. v. Mahon* (1922) 260 U.S. 393, 415.)

Courts have struggled in the 90 years since then to give agencies and property owners a more definite sense of exactly when a regulation "goes too far." The Supreme Court has identified three basic categories of takings that can occur in the context of land use regulation. Different legal standards apply depending on what kind of taking is at issue. (See, generally, *Lingle v. Chevron USA, Inc.* (2005) 544 U.S. 528).

The most straightforward test applies to what is variously called a categorical, total, *per se*, or *"Lucas"* takings, which occurs when a regulation deprives an owner of all economically beneficial use of the property. (See *Lucas v. South Carolina Coastal Council* (1992) 505 U.S. 1003). An agency that completely deprives a property owner of all economically beneficial use of the property will likely be found liable for a taking unless background principles of nuisance or property law independently restrict the owner's intended use of the property. Courts have generally been very strict about when they apply this test. If any economically beneficial use remains after application of the regulation, even if the value of that use is a very small percentage of the value of the property absent the regulatory restriction, a *Lucas* taking has not occurred.

Where a regulation significantly reduces the value of private property but does not completely deprive the owner of all economically beneficial use, the multi-factor "*Penn-Central"* test applies (*Penn Central Transportation Co. v. City of New York* (1978) 438 U.S. 104). This test has no set formula, but the primary factors include the economic impact of the regulation, the extent to which the regulation interferes with distinct, reasonable investment-backed expectations, and the character of the governmental action. When evaluating the character of the governmental action, courts consider whether the regulation amounts to a physical invasion or instead more generally affects property interests through a program that adjusts the burdens and benefits of economic life for the common good. Whether a regulation was in effect at the time an owner acquired title is also a relevant factor, but is not by itself dispositive. (See *Palazzolo v. Rhode Island* (2001) 533 U.S. 606, 632-633 (O'Connor, J., concurring)). Because this test takes such a wide range of factors into account, caselaw does not provide clear guidance about the situations in which a regulation is likely to qualify as a "*Penn-Central"* taking. A *Penn-Central*

claim is unlikely to succeed, however, unless the plaintiff can establish that the regulation very substantially reduces the value of the property.

The third category of takings claims applies to "exactions," that is, government permitting decisions that require a property owner either to convey a property interest or to pay a mitigation fee as a condition of approval. (See *Nollan v. California Coastal Comm.* (1987) 483 U.S. 825; *Dolan v. City of Tigard* (1994) 512 U.S. 374; *Koontz v. St. Johns River Water Management Dist.* (2013) 133 S.Ct. 2586). Under the *Nollan/Dolan* line of cases, the agency must establish a "nexus" between the condition requiring a property interest or payment and the effects of the project that that property interest or payment is mitigating. That property interest or payment must also be roughly proportional to the impact that it is intended to mitigate. In California, the *Ocean Harbor House* case is a good example of a shoreline structure impact mitigation requirement that was found by the courts to meet the relevant standards of nexus and proportionality.

Various recommendations of this Guidance may potentially give rise to takings concerns. Because the determination of whether a particular regulation may in some circumstances be applied in a way that constitutes a taking is so fact-intensive and context-specific, this Guidance cannot provide a simple set of parameters for when agencies should either allow exceptions to a land use regulation or consider purchasing a property interest. That said, land use restrictions that prevent all economically beneficial use of the entirety of a property[53] are vulnerable to *Lucas* takings claims unless those uses would qualify as a nuisance or are prohibited by property law principles such as the public trust doctrine. Agencies can minimize the risk of these claims by allowing economically beneficial uses on some of the property and by exploring whether legal doctrines regarding nuisance, changing shoreline property lines, or the public trust independently allow for significant limitations on the use of the property. Establishing a transferrable development rights program for properties that are subject to significant development restrictions may also minimize potential exposure to takings claims.

Where a proposed development would be safe from hazards related to sea level rise in the near future, but cannot be sited so as to avoid those risks for the expected life of the structure, agencies may consider allowing the structure, but requiring removal once it is threatened. Property owners may argue that they have a right to protect threatened structures even if they have waived rights to shoreline protection under the Coastal Act, but a recent federal court of appeal ruling casts significant doubt on the existence of any common law right to attempt to fix an ambulatory shoreline boundary through artificial structures such as seawalls (see *United States v. Milner* (9th Cir. 2009) 583 F.3d 1174, 1189-1190).

If an agency is contemplating requiring property owners to dedicate open space easements or other property interests or requiring the payment of fees to mitigate project impacts, the agency should be careful to adopt findings explaining how requiring the property interest or payment is

[53] What qualifies as the entirety of a property can also be the subject of dispute. The property will normally include all legal lots on which the proposed development would be located, but can also include other lots that are in common ownership and adjacent to, or in close proximity with, the lots that would be developed. (See *Norman v. United States* (Fed. Cir. 2005) 429 F.3d 1081, 1091; *District Intown Properties Limited Partnership v. District of Columbia* (D.C. Cir. 1999) 198 F.3d 874, 880.).

both logically related to mitigating an adverse impact of the project and roughly proportional to that impact. Legislatively adopting rules that establish the exact criteria for determining when to require these exactions and, if so, their magnitude, may also reduce an agency's exposure to takings claims.[54] With respect to mitigation fees, California cities and counties should also comply with applicable requirements of the Mitigation Fee Act (Government Code, §66000 *et seq.*).

[54] The California Supreme Court has ruled that courts should be more deferential towards agencies when reviewing fees imposed pursuant to legislatively enacted rules of general applicability than when reviewing fees imposed on an ad hoc basis. (*Ehrlich v. City of Culver City* (1996) 12 Cal.4th 854, 881.) The rationale is that fees imposed pursuant to rules of general applicability that involve little discretion are less likely to impose disproportionate burdens on property owners than fees determined on an ad hoc basis.

Chapter 9

Next Steps

CURRENT AND FUTURE COASTAL COMMISSION EFFORTS:

The Commission has a Strategic Plan for 2013-2018 (2013a) that identifies many action items that the Commission or partner organizations plan to take to address the challenges of sea level rise and climate change. The first priority in the Strategic Plan is for the Commission to adopt Sea Level Rise Policy Guidance for use in Local Coastal Program (LCP) planning and project design (Action 3.1.1), and this Guidance reflects significant progress toward accomplishing this task. The objectives and action items from the Strategic Plan related to sea level rise and climate change are presented within the following pages.

The Commission is also involved in a number of other efforts that meet the climate change planning goals laid out in its Strategic Plan. These include efforts related to the Commission's normal operating business, such as ongoing coordination with local government partners and other agencies, as well as specially funded projects designed to meet specific needs. Several of these efforts that are currently underway or that staff identified as next steps during the completion of this Guidance document are listed below. The Commission anticipates that these items will be completed over the next two to five years, in coordination with other relevant partners and research institutions, as staff capacity and funding allows.

1. **Continue an active program of public outreach on sea level rise.** The Commission will strive to provide public information about sea level rise issues through public workshops, the Commission's website, meetings, outreach, and our public education program. The Commission will work to enhance efforts to coordinate with low-income and underserved populations and communities.

2. **Develop methods for quantifying impacts to coastal resources from shoreline armoring projects.** The Coastal Commission staff has initiated a Project of Special Merit (funded by NOAA) to build upon the Commission's existing efforts to mitigate for the adverse impacts of shoreline development projects to public access and recreation by working with beach ecologists and a valuation economist to develop a method to quantify impacts to biological resources and beach ecology. The final product is anticipated to be a set of guidelines to use in assessing the impacts of proposed shoreline armoring projects and a method(s) for calculating the full value of recreational and ecological loss resulting from installation of shoreline armoring projects (where they may be approved as consistent with the Coastal Act).

3. **Adopt policy guidance and model ordinance language for resilient shoreline residential development in hazardous areas affected by sea level rise.** Under another NOAA-funded Project of Special Merit, the Coastal Commission will conduct a statewide survey to characterize physical shoreline conditions for residential areas along the coast. Informed by this assessment, staff will identify and analyze policy and legal issues for development and redevelopment in hazardous areas, factoring in sea level rise projections that will change shoreline conditions over time. Working collaboratively with local governments, staff will use the policy and legal analysis to develop policy guidance and model ordinance language. The project will build upon this Guidance and is consistent with the Coastal Commission's Strategic Plan goals.

4. **Enhance coordination and planning efforts related to developing adaptation strategies for critical infrastructure.** Addressing sea level rise impacts to critical infrastructure is particularly complex and will require greater amounts of planning time, stakeholder input, and funding. The Commission will support planning efforts in a number of ways including, for example:

    a. Providing guidance or participating in working groups that examine managed retreat of critical infrastructure, including when to consider managed retreat rather than continue with repairs and maintenance in light of sea level rise.

    b. Coordinating closely with Caltrans to address transportation issues. Planning efforts may include integrating LCP planning and regional transportation planning processes; coordinating and supporting phased approaches for realignment projects; and identifying priorities for adaption response.

    c. Coordinating with port and harbor authorities and other relevant stakeholders to address vulnerabilities specific to ports, harbors, fisheries, and navigation, and to develop and enhance adaptation strategies that are particularly applicable for coastal-dependent infrastructure and other port needs.

    d. Coordinating with the State and Regional Water Quality Control Boards to consider vulnerability issues related to water supply and wastewater capacity infrastructure in California.

5. **Consider producing additional guidance documents, including**:

    a. Broader climate change guidance addressing other climate change impacts to the coastal zone.

    b. One-page fact sheets on some adaptation measures such as green infrastructure and conservation easements.

    c. Guidance on the use of ‘living shorelines’, dune management, beach nourishment, and so on for California, including an assessment of areas or coastal situations where these strategies could be effective, what they need to succeed, monitoring requirements, and maintenance.

    d. Guidance for how to address impacts to critical infrastructure, assets and resources that cross jurisdictional boundaries, and ports, harbors and other coastal-dependent resources.

6. **Implement the Coastal Commission’s responsibilities under other state efforts and legislation.**

    a. Governor Brown’s April 2015 Executive Order B-30-15 states that state agencies shall take climate change into account in their planning and investment decisions, and employ full life-cycle cost accounting to evaluate and compare infrastructure investments and alternatives. The order requires agencies to ensure that priority is given to actions that build climate preparedness and reduce greenhouse gas emissions, provide flexible and adaptive approaches, protect the state's most vulnerable

populations, and promote natural infrastructure solutions. The Coastal Commission will continue to integrate these principles into its planning and regulatory work.

b. AB2516, authored by Assemblymember Gordon and approved in September 2014, established a *Planning for Sea Level Rise Database* that is anticipated to be available online in early 2016. The database will provide the public with an educational tool from which to learn about the actions taken by cities, counties, regions, and various public and private entities to address sea level rise. The Coastal Commission will contribute data to this effort, including information about grant-funded LCP updates.

c. The Coastal Commission will also participate in the implementation of the 2014 *Safeguarding California* plan, along with the Ocean Protection Council's 2014 Resolution on the Implementation of the Safeguarding California Plan. Key principles are and will continue to be incorporated into Coastal Commission work, including protection of California's most vulnerable populations the integration of risk reduction with emissions reductions, and the development of metrics and indicators of progress on efforts to reduce climate risk.

Coastal Commission Strategic Plan 2013-2018 Excerpts
Actions Related to Sea Level Rise and Climate Change

GOAL 1: Maximize Public Access and Recreation

Objective 1.1 – Enhance Public Access through Updated Beach Access Assessment and Constraints Analysis

Actions:

1.1.5 Identify locations where access may be limited or eliminated in the future due to sea level rise and increased storm events and begin planning for other options such as new vertical accessways to maintain maximum beach access (see also Action 3.2.1).

Objective 1.4 – Expand the California Coastal Trail System through Enhanced Planning and Implementation

Actions:

1.4.4 Identify locations of the CCT that might be at risk from rising sea level and increased storm events and begin planning for trail relocations or other alternatives to insure continued functionality of the CCT (see also Action 3.2.1).

GOAL 3: Address Climate Change through LCP Planning, Coastal Permitting, Inter-Agency Collaboration, and Public Education

Objective 3.1 – Develop Planning and Permitting Policy Guidance for Addressing the Effects of Climate Change on Coastal Resources

Actions:

3.1.1 Adopt general sea level rise (SLR) policy guidance for use in coastal permitting and LCP planning, and amendments based on best available science, including the final report

from the National Research Council of the National Academy of Science entitled *Sea-Level Rise for the Coasts of California, Oregon, and Washington* (June 2012).

3.1.2 Based on the general SLR policy guidance, identify and develop specific regulatory guidance for addressing coastal hazards, including recommendations for analytic methods for accounting for SLR and increased storm events in project analysis, standards for redevelopment and development in hazard zones (*e.g.*, bluff top and flood zones), buffers for coastal wetlands, and policies for shoreline structure design and impact mitigation.

3.1.3 Develop a work program to produce policy guidance for coastal permitting and LCPs, to account for other climate change related impacts and adaptation planning including wetland, marine and terrestrial habitat protection, habitat migration, risk of wildfires, water supply and groundwater protection.

3.1.4 Provide public information and guidance through workshops, presentations to local government, *etc.* Assist local governments with interpretation of scientific or other technical information related to climate change and sea level rise that could be of use in adaptation planning.

3.1.5 Contribute to relevant state-wide efforts on climate change and adaptation as a member of the State's Climate Action Team – Coast and Ocean Working Group.

3.1.6 Coordinate with Natural Resources Agency, Office of Planning and Research, California Governor's Office of Emergency Services (Cal OES) and others to provide consistent guidance on climate change in updating general plans, hazard mitigation plans and other planning documents used by local governments.

3.1.7 Coordinate with the State Lands Commission to address sea level rise and shoreline change and implications for the management of public trust resources.

Objective 3.2 – Assess Coastal Resource Vulnerabilities to Guide Development of Priority Coastal Adaptation Planning Strategies

Actions:

3.2.1 Conduct a broad vulnerability assessment of urban and rural areas to identify priority areas for adaptation planning, such as community development, public infrastructure, public accessways, open space or public beaches at risk from sea level rise. Identify and participate in on-going vulnerability assessments and adaptation planning efforts as feasible.

3.2.2 Work with CalTrans and other public agency partners to assess and address roadway, rail, and other transportation infrastructure vulnerabilities, particularly along Highway One and other coastal roads and highways.

3.2.3 Work with the Department of Water Resources, State Water Resources Control Board, and local agencies to assess and address water and wastewater treatment plant vulnerabilities along the coast.

3.2.4 Work with the Conservancy, California Department of Fish and Game *[sic]*, US Fish and Wildlife, and other partners to assess the vulnerability of wetlands and other sensitive habitat areas. Identify habitats that are particularly vulnerable climate change and/or

habitats that may be important for future habitat migration (*e.g.*, wetland transitional areas).

3.2.5 Work with the Coastal Observing Systems, researchers, and others to identify and develop baseline monitoring elements to better understand and monitor changes in coastal conditions related to sea level rise and other climate change impacts.

3.2.6 With the Conservancy and OPC, develop and implement a competitive grant program to provide funding to selected local governments to conduct vulnerability assessments and/or technical studies that can be used to assess a community's risks from climate change and inform updates to LCPs.

ADDITIONAL RESEARCH NEEDS

Additional research is needed to more fully understand and prepare for sea level rise. The research needs are directed toward research institutions at academic, state, federal, and local levels. The Commission will strive to collaborate with and support research related to sea level rise science and adaptation, including with the efforts and ongoing work of the California Climate Change Research Plan.

1. **Modeling.** Sea level rise science is an evolving field, and new science is expected to change and refine our understanding of the dynamics of sea level rise and its associated impacts to both natural and built environments. As such, there is a continual need for models to be developed, updated, and refined to ensure that we continue to have the best understanding of sea level rise-related impacts as possible. In some cases, the modelling capabilities already exist, but there is a need for such modelling to be applied to local areas to understand specific localized impacts. Several topics in particular that are in need of better or more refined modeling include:
    a. Fluvial dynamics as they relate to and interact with rising sea levels
    b. Habitat evolution models (*e.g.*, SLAMM) that project future locations of wetlands and other coastal habitats
    c. The interaction of other climate change-related impacts with the impacts of sea level rise (*e.g.*, changing precipitation patterns, increased frequency and/or intensity of storms)

2. **Improved estimates of local vertical land motion.** Several independent processes – glacial isostatic rebound, groundwater withdrawals, plate movements and seismic activity – influence vertical land motion. Current guidance on sea level projections adjusts for large-scale vertical land motion north and south of Cape Mendocino. These adjustments do not properly address locations that are moving differently from the region, such as Humboldt Bay. A peer-reviewed methodology is needed to determine:
    a. Instances when it will be important to modify the regional sea level rise projections for local vertical land motion
    b. Types of existing information on land motion (*e.g.*, tide gauge records, satellite data, land-based GPS stations) that provide the best estimates of local land trends

c. A procedure for adjusting state or regional sea level rise projections for sub-regional or local conditions

d. Additional data that are needed to implement this procedure

3. **Baseline data and monitoring systems**. Baseline monitoring data are needed for coastal and nearshore waters, beaches, bluffs, dune systems, nearshore reefs, tide pools, wetlands, and other habitat areas to better understand these systems, monitor trends, and detect significant deviations from historic conditions that may be related to sea level rise and other aspects of climate change. Better storm event monitoring data are also needed to support refinements and calibration of models used to project and analyze impacts.

   A system for monitoring and tracking the cumulative impacts of projects in the coastal zone, including both new development and any adaptation strategies, is needed to better understand the impacts of development in the face of sea level rise and the efficacy of various adaptation methods. Monitoring systems may be needed at a variety of scales, including at the local, regional, and state level.

4. **Methods for estimating change in erosion rates and shoreline change due to future sea level rise.** There is a need for a peer-reviewed methodology for estimating change in erosion rates due to sea level rise for bluffs, beaches, and other shorelines exposed to erosion. An improved understanding of future erosion rates is necessary to better evaluate projects affected by such erosion, including in terms of calculating an appropriate setback distance.

5. **Analysis of sea level rise impacts to coastal access and recreation.** To improve public access planning efforts, more information is needed about how sea level rise could affect public access areas and recreation throughout the state, including changes to waves and surfing, and the potential economic costs of these impacts. Additional information about how these changes will affect lower-income populations and underserved communities is particularly important.

   Many currently accessible beach areas have the potential to become inaccessible due to impacts from sea level rise. Shoreline armoring and emerging headlands could isolate connected beaches with sea level rise, which will block lateral access. Rising sea level will also tend to constrict beaches that are prevented from migrating landward by shoreline armoring and development. Some blufftop trails will become inaccessible as segments of trail are lost to erosion. In addition, changes in beach conditions and sediment dynamics due to sea level rise could affect waves and surfing, as can the rise itself by potentially 'drowning out' surf spots combined with the lack of space available for these spots to move (*e.g.*, where new 'tripping' elements can be encountered in the right depth of water to create surfable waves). Research on the specifics of these impacts will help the Commission and others understand the details of the potential impacts to coastal access and recreation.

6. **Methods to evaluate impacts to coastal resources from shoreline protection.** Research is needed to develop and improve methods to evaluate and mitigate for the adverse impacts to recreation, public access and beach ecology from shoreline armoring projects. This information will be used to determine a set of mitigation options that may be considered for use when evaluating individual permit applications to offset anticipated losses to beach

ecology and resources caused by shoreline armoring projects. The Coastal Commission staff is currently working on developing resource valuation guidelines as part of a Project of Special Merit (see Coastal Commission Effort #2).

7. **Analysis of sea level rise impacts to wetlands and strategies for preserving wetlands throughout the state.** Additional research is needed to assess the vulnerability of wetlands and other sensitive habitat areas to climate change, and to identify adjacent areas that may be important for future habitat migration (*e.g.*, wetland transitional areas). Further work is also needed to develop management strategies that are adaptable to local wetland conditions and sea level rise impacts, such as the following:
    a. Methodologies for establishing natural resource area buffer widths in light of sea level rise
    b. Approaches for identifying and protecting migration corridors
    c. Guidance for increasing wetland sediment supply and retention
    d. Techniques for developing an adaptive wetland restoration plan
    e. Monitoring criteria

8. **Assessment of coastal habitat functions in light of sea level rise and other climate change impacts.** It is necessary to develop a better understanding of the value and benefits that intact natural habitats provide, especially as they relate to increasing coastal resiliency to sea level rise. In addition, further research is needed to identify the coastal habitats that are most likely to experience adverse impacts from sea level rise and extreme storms, and what the associated loss of ecosystem services will mean for coastal populations. Research is also needed to identify strategies to ameliorate the vulnerabilities.

9. **Potential effects of sea level rise on groundwater and coastal aquifers.** Additional research is needed to quantify the potential effect of sea level rise on freshwater aquifers located along the California coast, and the degree to which sea level rise could lead to new incidences of intrusion. Research should include: (a) an evaluation of the potential incidence and severity of saltwater intrusion at the scale of individual aquifers, under various sea level rise scenarios, (b) criteria to use when deciding if saltwater intrusion requires mitigation or response and (c) identification of strategies to address the impacts rising groundwater and saltwater intrusion have on agriculture.

10. **Analysis of non-environmental factors that influence sea level rise adaptation.** As suggested in a number of places throughout this Guidance, there are factors beyond just environmental concerns that will influence sea level rise planning. Such factors include environmental justice/social equity, economic, and legal considerations, among others. Understanding how these social concerns interact with environmental vulnerabilities will be important when assessing adaptation planning opportunities and challenges.

Glossary

The following terms were collected from the 2009 *California Climate Change Adaptation Strategy*[55], the Intergovernmental Panel on Climate Change Third Assessment Report[56], the Coastal Commission's Beach Erosion and Response (BEAR) document,[57] and the California Coastal Act, unless otherwise noted. Some of these definitions are not used in the text of the report, but are included as a resource on coastal-related adaptation issues.

Adaptation: Adjustment in natural or human systems in response to actual or expected climatic stimuli or their effects, which minimizes harm or takes advantage of beneficial opportunities.

Adaptive capacity: The ability of a system to respond to climate change (including climate variability and extremes), to moderate potential damages, to take advantage of opportunities, and to cope with the consequences.[58]

Adaptive management: Involves monitoring the results of a management decision, and updating actions as needed and as based on new information and results from the monitoring.

Ambulatory (*as used in public trust boundaries*): Moveable, subject to change, or capable of alteration.[59]

Aquifer: An underground layer of porous rock, sand, or other earth material containing water, into which wells may be sunk.

Armor: To fortify a topographical feature to protect it from erosion (*e.g.*, constructing a wall to armor the base of a sea cliff), or to construct a feature (*e.g.*, a seawall, dike, or levee) to protect other resources (*e.g.*, development or agricultural land) from flooding, erosion, or other hazards.

Atmosphere-Ocean General Circulation Models (or Atmosphere-Ocean General Climate Models; ACGOM): Three-dimensional global models that dynamically link ocean density, circulation, and sea level using wind stress, heat transfer between air and sea, and freshwater fluxes as critical variables. (See also *General Circulation Models*)

Baseline (or Reference): Any datum against which change is measured. It might be a "current baseline," in which case it represents observable, present-day conditions. It might also be a "future baseline", which is a projected future set of conditions excluding the driving factor of interest (*e.g.*, how would a sector evolve without climate warming). It is critical to be aware of what change is measured against which baseline to ensure proper interpretation. Alternative interpretations of the reference conditions can give rise to multiple baselines.[60]

[55] CNRA 2009

[56] IPCC 2001

[57] Many of these definitions were extracted from: USACE 1984, Griggs and Savoy 1985 and Flick 1994.

[58] Willows and Connell 2003

[59] *West's Encyclopedia of American Law* 2008

[60] Moser 2008

Beach: The expanse of sand, gravel, cobble or other loose material that extends landward from the low water line to the place where there is distinguishable change in physiographic form, or to the line of permanent vegetation. The seaward limit of a beach (unless specified otherwise) is the mean low water line.

Beach nourishment: Placement of sand and/or sediment (*e.g.,* beneficial re-use of dredged sediment) on a beach to provide protection from storms and erosion, to create or maintain a wide(r) beach, and/or to aid shoreline dynamics throughout the littoral cell. The project may include dunes and/or hard structures as part of the design.

Bluff (or Cliff): A scarp or steep face of rock, weathered rock, sediment and/or soil resulting from erosion, faulting, folding or excavation of the land mass. The cliff or bluff may be a simple planar or curved surface or it may be step-like in section. For purposes of (the Statewide Interpretive Guidelines), "cliff" or "bluff" is limited to those features having vertical relief of ten feet or more and "seacliff" is a cliff whose toe is or may be subject to marine erosion.

Bluff top retreat (or Cliff top retreat): The landward migration of the bluff or cliff edge, caused by marine erosion of the bluff or cliff toe and subaerial erosion of the bluff or cliff face.

Caisson: A supporting piling constructed by drilling a casing hole into a geologic formation and filling it with reinforcing bar and concrete; used for foundations. (See also *Piling*)

Climate change: Any long-term change in average climate conditions in a place or region, whether due to natural causes or as a result of human activity.

Climate variability: Variations in the mean state of the climate and other statistics (*e.g.*, standard deviations, the occurrence of extremes) on all temporal and spatial scales beyond that of individual weather events.

Coastal-dependent development or use: Any development or use which requires a site on, or adjacent to, the sea to be able to function at all.[61]

Coastal-related development: Any use that is dependent on a coastal-dependent development or use.[62]

Coastal resources: A general term used throughout the Guidance to refer to those resources addressed in Chapter 3 of the California Coastal Act, including beaches, wetlands, agricultural lands, and other coastal habitats; coastal development; public access and recreation opportunities; cultural, archaeological, and paleontological resources; and scenic and visual qualities.

Development: On land, in or under water, the placement or erection of any solid material or structure; discharge or disposal of any dredged material or of any gaseous, liquid, solid, or

[61] Public Resources Code § 30101

[62] Public Resources Code § 30101.3

thermal waste; grading, removing, dredging, mining, or extraction of any materials; change in the density or intensity of use of land, including, but not limited to, subdivision pursuant to the Subdivision Map Act (commencing with Section 66410 of the Government Code), and any other division of land, including lot splits, except where the land division is brought about in connection with the purchase of such land by a public agency for public recreational use; change in the intensity of use of water, or of access thereto; construction, reconstruction, demolition, or alteration of the size of any structure, including any facility of any private, public, or municipal utility; and the removal or harvesting of major vegetation other than for agricultural purposes, kelp harvesting, and timber operations which are in accordance with a timber harvesting plan submitted pursuant to the provisions of the Z'berg-Nejedly Forest Practice of 1973 (commencing with Section 4511).[63]

Ecosystem-Based Management (EBM): An integrated approach to resource management that considers the entire ecosystem, including humans, and the elements that are integral to ecosystem functions.[64]

Ecosystem services: Benefits that nature provides to humans. For example, plants, animals, fungi and micro-organisms produce services or goods like food, wood and other raw materials, as well as provide essential regulating services such as pollination of crops, prevention of soil erosion and water purification, and a vast array of cultural services, like recreation and a sense of place.[65]

Emissions scenarios: Scenarios representing alternative rates of global greenhouse gas emissions growth, which are dependent on rates of economic growth, the success of emission reduction strategies, and rates of clean technology development and diffusion, among other factors.[66]

Environmentally Sensitive [Habitat] Area (ESHA): Any area in which plant or animal life or their habitats are either rare or especially valuable because of their special nature or role in an ecosystem and which could be easily disturbed or degraded by human activities and developments.[67]

Erosion: The wearing away of land by natural forces; on a beach, the carrying away of beach material by wave action, currents, or the wind. Development and other non-natural forces (*e.g.*, water leaking from pipes or scour caused by wave action against a seawall) may create or worse erosion problems.

Eustatic: Refers to worldwide changes in sea level.

[63] Public Resources Code § 30106

[64] NOC 2011

[65] Hassan *et al.* 2005

[66] Bedsworth and Hanak 2008

[67] Public Resources Code § 30107.5

Feasible (*as used in "least environmentally damaging feasible alternative"*): Capable of being accomplished in a successful manner within a reasonable period of time, taking into account economic, environmental, social, and technological factors.[68]

Flood (or Flooding): Refers to normally dry land becoming temporarily covered in water, either periodically (*e.g.*, tidal flooding) or episodically (*e.g.*, storm or tsunami flooding).[69]

General Circulation Models (or General Climate Models; GCM): A global, three-dimensional computer model of the climate system which can be used to simulate human-induced climate change. GCMs are highly complex and they represent the effects of such factors as reflective and absorptive properties of atmospheric water vapor, greenhouse gas concentrations, clouds, annual and daily solar heating, ocean temperatures and ice boundaries. The most recent GCMs include global representations of the atmosphere, oceans, and land surface.[70] (See also *Atmospheric-Ocean General Circulation Models*)

Green infrastructure: Refers to the use of vegetative planting, dune management, beach nourishment or other methods that mimic natural systems to capitalize on the ability of these systems to provide flood and erosion protection, stormwater management, and other ecosystem services while also contributing to the enhancement or creation of natural habitat areas.

Greenhouse gases (GHGs): Any gas that absorbs infrared radiation in the atmosphere. Greenhouse gases include, carbon dioxide, methane, nitrous oxide, ozone, chlorofluorocarbons, hydrochlorofluorocarbons, hydrofluorocarbons, perfluorocarbons, sulfur hexafluoride.[71]

Hard protection: A broad term for most engineered features such as seawalls, revetments, cave fills, and bulkheads that block the landward retreat of the shoreline. (See also *Revetment, Seawall, Shoreline protective devices*)

Impact assessment: The practice of identifying and evaluating the detrimental and beneficial consequences of climate change on natural and human systems.

Inundation: The process of dry land becoming permanently drowned or submerged, such as from dam construction or from sea level rise.[72]

Local Coastal Program (LCP): A local government's (a) land use plans, (b) zoning ordinances, (c) zoning district maps, and (d) within sensitive coastal resources areas, other implementing actions, which, when taken together, meet the requirements of, and implement the provisions and policies of, this division at the local level.[73]

[68] California Coastal Act § 30108

[69] Flick *et al.* 2012

[70] NASA Earth Observatory Glossary

[71] UNFCCC 2004

[72] Flick *et al.* 2012

[73] Public Resources Code § 30108.6

Mean sea level: The average relative sea level over a period, such as a month or a year, long enough to average out transients such as waves and tides. Relative sea level is sea level measured by a tide gauge with respect to the land upon which it is situated. (See also *Sea level change/sea level rise*)

Mitigation (*as used in climate science*): A set of policies and programs designed to reduce emissions of greenhouse gases.[74]

Mitigation (*as used in resource management*): Projects or programs intended to offset impacts to resources.

Monitoring: Systematic collection of physical, biological, chemical, or economic data, or a combination of these data on a project in order to make decisions regarding project operation or to evaluate project performance.

Passive erosion: The process whereby erosion causes the shoreline to retreat and migrate landward of any hardened structures that have fixed the location of the back beach therefore resulting in the gradual loss of beach in front of the hardened structure.

Permit: Any license, certificate, approval, or other entitlement for use granted or denied by any public agency which is subject to the provisions of this division.[75]

Piling (or Pile): A long, heavy timber or section of concrete or metal driven or drilled into the earth or seabed to serve as a support or protection. (See also *Caisson*)

Potential impacts: All impacts that may occur given a projected change in climate, including impacts that may result from adaptation measures.

Public Trust Lands: All lands subject to the Common Law Public Trust for commerce, navigation, fisheries, recreation, and other public purposes. Public Trust Lands include tidelands, submerged lands, the beds of navigable lakes and rivers, and historic tidelands and submerged lands that are presently filled or reclaimed and which were subject to the Public Trust at any time.[76] (See also *Tidelands, Submerged lands*)

Radiative forcing: Radiative forcing is a measure of the influence a factor has in altering the balance of incoming and outgoing energy in the Earth-atmosphere system and is an index of the importance of the factor as a potential climate change mechanism. In [the IPCC] report radiative forcing values are for changes relative to pre-industrial conditions defined at 1750 and are expressed in Watts per square meter (W/m^2).[77]

[74] Luers and Moser 2006

[75] Public Resources Code § 30110

[76] Public Resources Code § 13577

[77] IPCC 2007

Redevelopment: At a minimum, replacement of 50% or more of an existing structure. LCPs may also consider including limits on the extent of replacement of major structural components such as the foundation or exterior walls, or improvements costing more than 50% of the assessed or appraised value of the existing structure**.**

Revetment: A sloped retaining wall; a facing of stone, concrete, blocks, rip-rap, *etc.* built to protect an embankment, bluff, or development against erosion by wave action and currents. (See also *Hard protection, Seawall, Shoreline protective devices*)

Risk: Commonly considered to be the combination of the likelihood of an event and its consequences – *i.e.*, risk equals the probability of climate hazard occurring multiplied the consequences a given system may experience.[78]

Scenario-based analysis: A tool for developing a science-based decision-making framework to address environmental uncertainty. In general, a range of plausible impacts based on multiple time scales, emissions scenarios, or other factors is developed to inform further decision-making regarding the range of impacts and vulnerabilities.[79]

Sea level: The height of the ocean relative to land; tides, wind, atmospheric pressure changes, heating, cooling, and other factors cause sea level changes.

Sea level change/sea level rise: Sea level can change, both globally and locally, due to (a) changes in the shape of the ocean basins, (b) changes in the total mass of water and (c) changes in water density. Factors leading to sea level rise under global warming include both increases in the total mass of water from the melting of land-based snow and ice, and changes in water density from an increase in ocean water temperatures and salinity changes. Relative sea level rise occurs where there is a local increase in the level of the ocean relative to the land, which might be due to ocean rise and/or land level subsidence.[80] (See also *Mean sea level, Thermal expansion*)

Sea level rise impact: An effect of sea level rise on the structure or function of a system.[81]

Seawall: A structure separating land and water areas, primarily designed to prevent erosion and other damage due to wave action. It is usually a vertical wood or concrete wall as opposed to a sloped revetment. (See also *Hard protection, Revetment, Shoreline protective devices*)

Sediment: Grains of soil, sand, or rock that have been transported from one location and deposited at another.

[78] Burton *et al.* 2004

[79] NOAA 2010

[80] IPCC 2007

[81] PCGCC 2007

Sediment management: The system-based approach to the management of coastal, nearshore and estuarine sediments through activities that affect the transport, removal and deposition of sediment to achieve balanced and sustainable solutions to sediment related needs.

Sensitivity: The degree to which a system is affected, either adversely or beneficially, by climate-related stimuli. The effect may be direct (*e.g.*, a change in crop yield in response to a change in the mean, range, or variability of temperature) or indirect (*e.g.*, climatic or non-climatic stressors may cause people to be more sensitive to additional extreme conditions from climate change than they would be in the absence of these stressors).

Shore protection: Structures or sand placed at or on the shore to reduce or eliminate upland damage from wave action or flooding during storms.

Shoreline protective devices: A broad term for constructed features such as seawalls, revetments, riprap, earthen berms, cave fills, and bulkheads that block the landward retreat of the shoreline and are used to protect structures or other features from erosion and other hazards. (See also *Hard protection, Revetment, Seawall*)

Still water level: The elevation that the surface of the water would assume if all wave action were absent.

Storm surge: A rise above normal water level on the open coast due to the action of wind stress on the water surface. Storm surge resulting from a hurricane also includes the rise in water level due to atmospheric pressure reduction as well as that due to wind stress.

Submerged lands: Lands which lie below the line of mean low tide.[82] (See also *Public Trust Lands*, *Tidelands*)

Subsidence: Sinking or down-warping of a part of the earth's surface; can result from seismic activity, changes in loadings on the earth's surface, fluid extraction, or soil settlement.

Tectonic: Of or relating to the structure of the earth's crust and the large-scale processes that take place within it.

Thermal expansion: An increase in water volume in response to an increase in temperature, through heat transfer.

Tidal prism: The total amount of water that flows into a harbor or estuary and out again with movement of the tide, excluding any freshwater flow.

Tidal range: The vertical difference between consecutive high and low waters. The Great Diurnal Range is the difference between mean higher high water and mean lower low water; the Mean Range of tide is the difference in height between mean high water and mean low water.[83]

[82] Public Resources Code § 13577

[83] NOAA 2013

Tidelands: Lands which are located between the lines of mean high tide and mean low tide.[84] (See also *Public Trust Lands*, *Submerged lands*)

Transfer of Development Rights (TDR): A device by which the development potential of a site is severed from its title and made available for transfer to another location. The owner of a site within a transfer area may retain property ownership, but not approval to develop. The owner of a site within a receiving area may purchase transferable development rights, allowing a receptor site to be developed at a greater density.[85]

Tsunami: A long period wave, or seismic sea wave, caused by an underwater disturbance such as an earthquake, submarine landslide, or subaerial landslide (slope failure from land into a water body). Tsunamis can cause significant flooding in low-lying coastal areas and strong currents in harbors. (Commonly misnamed a *Tidal wave*)

Vulnerability: The extent to which a species, habitat, ecosystem, or human system is susceptible to harm from climate change impacts. More specifically, the degree to which a system is exposed to, susceptible to, and unable to cope with, the adverse effects of climate change, including climate variability and extremes. Vulnerability is a function of the character, magnitude, and rate of climate variation to which a system is exposed, as well as of non-climatic characteristics of the system, including its sensitivity, and its coping and adaptive capacity.

Vulnerability assessment: A practice that identifies who and what is exposed and sensitive to change and how able a given system is to cope with extremes and change. It considers the factors that expose and make people or the environment susceptible to harm and access to natural and financial resources available to cope and adapt, including the ability to self-protect, external coping mechanisms, support networks, and so on.[86]

Wave: A ridge, deformation, or undulation of the surface of a liquid. On the ocean, most waves are generated by wind and are often referred to as wind waves.

Wave height: The vertical distance from a wave trough to crest.

Wave length (or Wavelength): The horizontal distance between successive wave crests or between successive troughs of waves.

Wave period: The time for a wave crest to traverse a distance equal to one wavelength, which is the time for two successive wave crests to pass a fixed point.

Wave runup: The distance or extent that water from a breaking wave will extend up the shoreline, including up a beach, bluff, or structure.

[84] Public Resources Code § 13577

[85] Cal OPR 1987

[86] Tompkins *et al.* 2005

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Appendix A

Sea Level Rise Science and Projections for Future Change

DRIVERS OF SEA LEVEL RISE

The main mechanisms driving increases in *global* sea level are: 1) expansion of sea water as it gets warmer (thermal expansion) and, 2) increases in the amount of water in the ocean from melting of land-based glaciers and ice sheets as well as human-induced changes in water storage and groundwater pumping (Chao *et al.* 2008; Wada *et al.* 2010; Konikow 2011).[1] The reverse processes can cause global sea level to fall.

Sea level at the *regional and local levels* often differs from the average global sea level.[2] Regional variability in sea level results from large-scale tectonics and ocean and atmospheric circulation patterns. The primary factors influencing local sea level include tides, waves, atmospheric pressure, winds, vertical land motion and short duration changes from seismic events, storms, and tsunamis. Other determinants of local sea level include changes in the ocean floor (Smith and Sandwell 1997), confluence of fresh and saltwater, and proximity to major ice sheets (Clark *et al.* 1978; Perette *et al.* 2013).

Over the long-term, sea level trends in California have generally followed global trends (Cayan *et al.* 2009; Cayan *et al.* 2012). However, global projections do not account for California's regional water levels or land level changes. California's water levels are influenced by large-scale oceanographic phenomena such as the El Niño Southern Oscillation (ENSO) and the Pacific Decadal Oscillation (PDO), which can increase or decrease coastal water levels for extended periods of time. Figure A-1 shows how El Niño and La Niña events have corresponded to mean sea level in California in the past. California's land levels are also affected by plate tectonics and earthquakes. Changes to water as well as land levels are important factors in regionally down-scaled projections of future sea level. It follows that the sea level rise projections specific to California are more relevant to efforts in the coastal zone of California than projections of global mean sea level.

[1] Large movements of the tectonic plates have been a third major mechanism for changes in global sea level. The time periods for plate movements to significantly influence global sea level are beyond the time horizons used for even the most far-reaching land-use decisions. Plate dynamics will not be included in these discussions of changes to future sea level.

[2] For further discussion of regional sea level variations and regional sea level rise projections, see Yin *et al.* 2010, Slangen *et al.* 2012, and Levermann *et al.* 2013, as examples.

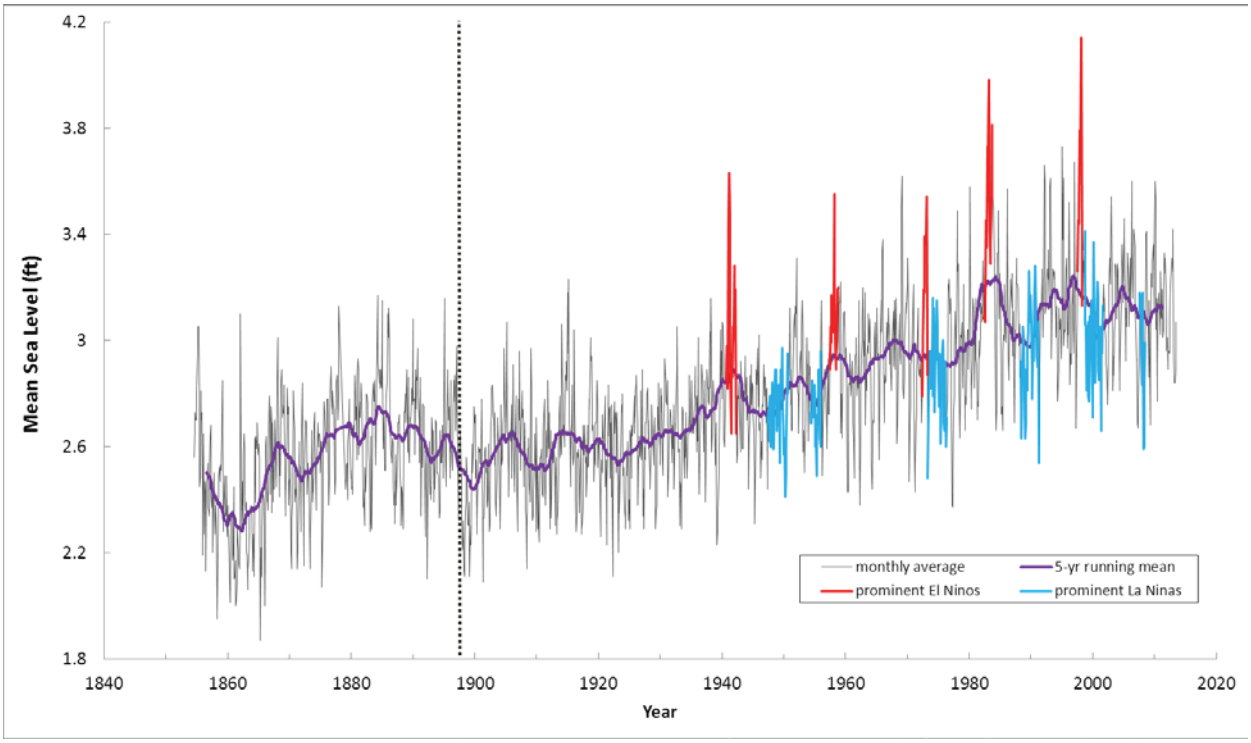

Figure A-1. Variations in monthly mean sea level at Fort Point, San Francisco, 1854 to 2013. Mean sea level heights (in ft) are relative to mean lower low water (MLLW). Purple line represents the 5-year running average. Note that the monthly mean sea level has varied greatly throughout the years and that several of the peaks occurred during strong El Niño events (red highlight). Periods of low sea level often occurred during strong La Niña events (blue highlight). The current "flat" sea level condition can also be seen in the 5-year running average. (*Sources: NOAA CO-OPS data, Station 9414290, http://tidesandcurrents.noaa.gov/ (sea level); NOAA Climate Prediction Center, http://www.elnino.noaa.gov/ (ENSO data)*)

APPROACHES FOR PROJECTING FUTURE GLOBAL SEA LEVEL RISE

This section provides an overview of some of the more well-known approaches that have been used to project sea level changes and their relevance to California. Appendix B will cover how these projections can be used to determine water conditions at the local scale.

There is no single, well-accepted technique for projecting future sea level rise. Understanding future sea level rise involves projecting future changes in glaciers, ice sheets, and ice caps, as well as future groundwater and reservoir storage. Two subjects in particular present challenges in sea level rise modeling. First, future changes to glaciers, ice sheets, and ice caps are not well understood and, due to the potential for non-linear responses from climate change, they present many difficulties for climate models (Overpeck 2006; Pfeffer *et al.* 2008; van den Broecke *et al.* 2011; Alley and Joughin 2012; Shepherd *et al.* 2012; Little *et al.* 2013). Second, the actual magnitudes of the two human-induced changes – pumping of groundwater and storage of water in reservoirs – are poorly quantified, but the effects of these activities are understood and can be modeled (Wada *et al.* 2010). Despite these challenges, sea level rise projections are needed for many coastal management efforts and scientists have employed a variety of techniques to model sea level rise, including:

1. Extrapolation of historical trends;
2. Modeling the physical conditions that cause changes in sea level;
3. Empirical or semi-empirical methods; and
4. Expert elicitations

There are strengths and weaknesses to each approach, and users of any sea level rise projections should recognize that there is no perfect approach for anticipating future conditions. This section provides users of the Guidance document with a general understanding of several of the most widely used sea level rise projection methodologies and their respective advantages and disadvantages. Figure A-2 provides a visual summary of several of the more commonly cited projections of future global and regional sea level rise.

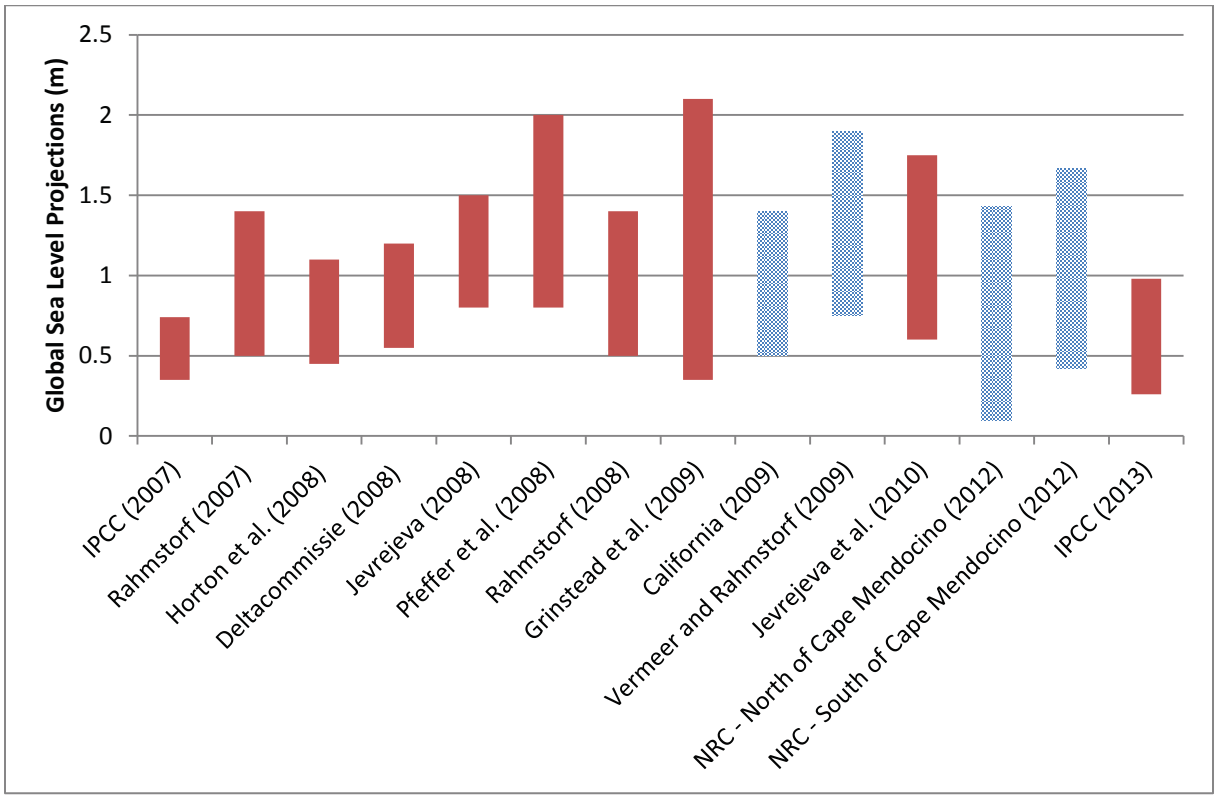

Figure A-2. Sea level rise projections for year 2100 from scientific literature. Graphic summary of the range of average sea level rise (SLR) projections by end of century (2090–2100) from the peer-reviewed literature as compared to the recent National Research Council report for California, Oregon and Washington. The light blue shaded boxes indicate projections for California. Ranges are based on the IPCC scenarios, with the low range represented by the B1 scenario (moderate growth and reliance in the future on technological innovation and low use of fossil fuels) and the high part of the range represented by the A1FI scenario (high growth and reliance in the future on fossil fuels). Details on the methods used and assumptions are provided in the original references.

Extrapolation of Historical Trends

Extrapolation of historical trends in sea level has been used for many years to project future changes in sea level. The approach assumes that there will be no abrupt changes in the processes that drive the long-term trend, and that the driving forces will not change. However, drivers of climate change and sea level rise, such as radiative forcing, are known to be changing, and this method is no longer considered appropriate or viable in climate science.

A recent modification to the historical trend method discussed above has been to estimate rates of sea level rise during the peak of the last interglacial (LIG) period (~125,000 years before present, when some drivers of sea level rise were similar to those today)[3] and use these as proxy records to project sea level rise rates to the 21st Century. For example, Katsman *et al.* (2011) and Vellinga *et al.* (2008) used the reconstructed LIG record of sea level change (from Rohling *et al.* 2008) to reconstruct sea level rise rates during rapid climate warming, and applied these rates to estimate sea level at years 2100 and 2200. Similarly, Kopp *et al.* (2009) used sea level rise rates inferred from the LIG to estimate a range of sea level rise for Year 2100 between 1-3 ft (0.3-1 m). Compared to traditional historical trend extrapolation, this modified approach has the advantage of including the dynamic responses of ice sheets and glaciers to past global climates that were significantly warmer than the present, but is limited by the large uncertainties associated with proxy reconstructions of past sea level.

Physical Models

Physical climate models use mathematical equations that integrate the basic laws of physics, thermodynamics, and fluid dynamics with chemical reactions to represent physical processes such as atmospheric circulation, transfers of heat (thermodynamics), development of precipitation patterns, ocean warming, and other aspects of climate. Some models represent only a few processes, such as the dynamics of ice sheets or cloud cover. Other models represent larger scale atmospheric or oceanic circulation, and some of the more complex General Climate Models (GCMs) include atmospheric and oceanic interactions.

Physical models of sea level changes account for the thermal expansion of the ocean and the transfer of water currently stored on land, particularly from glaciers and ice sheets (Church *et al.* 2011). Currently, coupled Atmosphere-Ocean General Circulation Models (AOGCMs) and ice sheet models are replacing energy-balance climate models as the primary techniques supporting sea level projections (IPCC 2013). Ocean density, circulation and sea level are dynamically connected in AOGCMs as critical components of the models include surface wind stress, heat transfer between air and sea, and freshwater fluxes. AOGCM climate simulations have recently been used as input for glacier models (Marzeion *et al.* 2012) which project land-water contributions to sea level.

The Intergovernmental Panel on Climate Change (IPCC) is one of the main sources of peer-reviewed, consensus-based modeling information on climate change. The IPCC does not undertake climate modeling, but uses the outputs from a group of climate models that project

[3] During the last interglacial, global mean temperature was 1-2ºC warmer than the pre-industrial era (Levermann *et al.* 2013), while global mean sea level was likely 16.4-29.5 ft (5-9 m) above present mean sea level (Kopp *et al.* 2009; Dutton and Lambeck 2012; Levermann *et al.* 2013).

future temperature, precipitation patterns, and sea level rise, based on specific emission scenarios. Early in the 1990s, the IPCC developed basic model input conditions to ensure comparable outputs from the various models. The IPCC initially developed scenarios of future emissions, based on energy development, population and economic growth, and technological innovation. Four families of scenarios (A1, A2, B1, and B2) and subgroups (A1B, A1FI, A1T) were developed and used for climate and sea level rise projections for early IPCC reports (1990, 1995, 2001, 2007). IPCC used 4 new scenarios for the *5th Assessment Report* (AR5) in 2013, based on Representative Concentration Pathways (RCPs) that are different greenhouse gas concentration trajectories. These trajectories bear similarities to, but are not directly comparable to the earlier emission scenarios. Projections in IPCC AR5 (2013) differ from the earlier IPCC projections due to improvements in climate science, changes due to the new scenarios, and changes in the models to accommodate the new inputs, with improvements in climate science and model capabilities driving the bulk of the changes.

One finding of the earlier 2007 IPCC report called for improved modeling of ice dynamics. Focused research on ice dynamics to improve the ability of climate models to address the scale and dynamics of change to glaciers, ice sheets, and ice caps was subsequently undertaken (*e.g.*, Price *et al.* 2011; Shepherd *et al.* 2012; Winkelman *et al.* 2012; Bassis and Jacobs 2013; Little *et al.* 2013). Recent modeling results presented in the AR5 (IPCC 2013) reflect the scientific community's increased understanding in, as well as advances in modeling of the impacts of glacier melting and ocean thermal expansion on sea level change. AR5 scenarios reflect a greater range of global sea level rise (28-98 cm) based on improved modelling of land-ice contributions.

Semi-Empirical Method

The semi-empirical method for projecting sea level rise is based on developing a relationship between sea level and some factor (a proxy) – often atmospheric temperature or radiative forcing – and using this relationship to project changes to sea level. An important aspect for the proxy is that there is fairly high confidence in models of its future changes; a key assumption that is made by this method is that the historical relationship between sea level and the proxy will continue into the future. One of the first projections of this kind was based on the historical relationship between global temperature changes and sea level changes (Rahmstorf 2007). This semi-empirical approach received widespread recognition for its inclusion of sea level rise projections. These projections looked at the temperature projections for two of the previous IPCC (2007) emission scenarios that span the likely future conditions within the report's framework – B1, an optimistic, low-greenhouse gas emission future, and A1FI, a more "business-as-usual" fossil fuel intensive future.[4] The Rahmstorf 2007 sea level rise projections were used in the California 2009 *Climate Change Scenarios Assessment* (Cayan 2009).

Since the initial semi-empirical projections for future sea level rise (Rahmstorf 2007), other researchers have published different projections based on the IPCC scenarios, using different

[4] When the IPCC began examining climate change, the available models used a broad range of inputs. In an attempt to evaluate the different model outputs based on the different model characteristics rather than the inputs, the IPCC developed a number of standard greenhouse gas emission scenarios. These scenarios are described in *Response Strategies Working Group III* (IPCC 1990). In general, the B1 scenario projects the lowest temperature and sea level increases and the A1FI projects the highest increases.

data sets or best-fit relationships.[5] Notably, Vermeer and Rahmstorf (2009) prepared a more detailed methodology that includes both short-term responses and longer-term responses between sea level rise and temperature. These 2009 projections of sea level rise were used in the *Interim Guidance on Sea Level Rise* (OPC 2010) and the California 2012 *Vulnerability and Assessment Report* (Cayan 2012).

There are also several new semi-empirical sea level rise projections based on scenarios other than those developed by the IPCC. For instance, Katsman *et al.* (2011) use a "hybrid" approach that is based on one of the newer radiative forcing scenarios and empirical relationships between temperature change and sea level. Future projections were then modified to include contributions from the melting of major ice sheets based on expert judgment[6]. This yields what they call "high end" SLR projections for Years 2100 and 2200 under several emissions scenarios.

Zecca and Chiari (2012) produced semi-empirical sea level rise projections based on their own scenarios of when fossil fuel resources would be economically exhausted. Though based on a different set of assumptions about human behavior/choices, in terms of global temperature and radiative forcing, the scenarios do not differ greatly from the IPCC scenarios. The results are identified as being "lower bound" sea level rise projections for high, medium, low fuel use scenarios, and "mitigation" (extreme and immediate action to replace fossil fuel use) scenarios. The report then provides projections for the 2000-2200 time period.

Expert Elicitation

Expert elicitation is one of the newer methods that have been used for projecting or narrowing ranges of future sea level rise. Using expert judgment has been an important aspect of scientific inquiry and the scientific method. The method of expert elicitation is a formalized use of experts in climate science and sea level change to help either narrow uncertainty for sea level projections, or to help with specifying extremes of a range. The elicitation method normally begins with experts refining model output information. One of the first attempts to use expert elicitation for sea level rise was a study by Titus and Narayanan (1996), when it was thought there was only 1% probability that sea level would exceed 3.3 ft (1 m) by Year 2100. In 2011, the Arctic Monitoring and Assessment Programme Report (AMAP 2011) surveyed the climate literature to construct a range of estimates of sea level rise by the year 2100, and then used a panel of experts to decide on a smaller, more plausible range. Not surprisingly, the projections supported by the AMAP experts fell right in the middle of the range shown in Figure A-2. Bamber and Aspinall (2013) used a statistical analysis of a large number of expert estimates to

[5] Semi-empirical projections of sea level rise using relationships between water level and radiative forcing such as those from Grinsted *et al.* (2009), Jevrejeva *et al.* (2010), Katsman *et al.* (2011), Meehl *et al.* (2012), Rahmstorf *et al.* (2012), Schaeffer *et al.* (2012), and Zecca and Chiari (2012) have shown general agreement with the projections by Vermeer and Rahmstorf (2009). The Grinsted *et al.* projections have a wider range than those of Vermeer and Rahmstorf, while the Jevrejeva *et al.* projections are slightly lower. All semi-empirical methods project that sea level in Year 2100 is likely to be much higher than linear projections of historical trends and the projections from the 2007 IPCC.

[6] Expert judgment has long been part of the scientific process. Expert elicitation, which is a formalized process for using expert judgment, has grown in importance and is discussed as a separate approach for projecting future sea level rise.

develop their projected range of future sea level, projecting sea level rise by 2100 ranging from 1–4.3 ft (0.33–1.32 m), under one of the intermediate AR5 scenarios (RCP 4.5).

Horton *et al.* (2014) surveyed experts in sea level science, based upon published papers, to develop a probabilistic assessment of long-term sea level rise (by the years 2100 and 2300), assuming two very different scenarios. Under one scenario, aggressive efforts would limit greenhouse gas concentrations that would cause global temperature to increase slightly until about 2050 when it would slowly drop (AR5's RCP 3 scenario). Under the other scenario, temperatures would continue to increase through to 2300 (AR5's RCP 8.5 scenario). Experts determined that it is likely that sea level rise could remain below 3.3 ft (1 m) for the low emission scenario (RCP 2.6), but that the likely range of future sea level rise for the high emission scenario (RCP 8.5) could be 6.6-9.8 ft (2-3 m).

Kopp *et al.* (2014) have combined detailed process modeling, community assessments and expert elicitation to assign probability distributions of local sea level rise through 2200 for identified communities around the world. Under the high concentration scenario, RCP 8.5, Kopp *et al.* estimate the "maximum physically possible rate of sea level rise" to be 8.2 ft (2.5 m) for the year 2100. This study also finds that sea level rise along the Pacific Coast of the US is close to the global average, and the likely range of sea level is 2-3.3 ft (0.6-1.0 m) by the year 2100 at San Francisco, under the high concentration scenario. In contrast, in areas of high subsidence such as Galveston, Texas, the likely range of sea level in by 2100 ranges from 3.3 to 5 ft (1.0-1.5 m). And, at many of the localities that were examined, including San Francisco, the current 1-in-10 year flooding event is likely to occur every other year by 2100 (five times more frequently) due to sea level rise; the frequency of the 1-in-100 year event is expected to double by the year 2100 with sea level rise.

Coastal communities cannot ignore sea level rise in long-term planning, permitting and project design. The four different approaches to projecting future sea level rise all have varying strengths and weaknesses. As noted earlier in this section, projections, like models, will not be completely accurate, but they are important tools for evaluation nonetheless[7]. The most commonly cited projections provide future sea level as a range, as a way to allow for many of the uncertainties that are part of future climate change. Often, projections of sea level rise rely upon multiple approaches. For example, the 2012 National Research Council (NRC) report, which is currently considered the best available sea level rise reference for the state of California, was developed through expert judgment that combined information from both physical models and semi-empirical projections.

[7] George E.P. Box, mathematician and statistician is quoted as saying, "Essentially all models are wrong, but some are useful."

BEST AVAILABLE SCIENCE ON SEA LEVEL RISE

Global Projections of Sea Level Rise

The best available science on *global* sea level rise projections is currently the IPCC *Fifth Assessment Report: Climate Change 2013* (AR5) released in September 2013. The new report now projects a more rapid sea level rise than the *Fourth Assessment* (AR4) released in 2007. By Year 2100, the AR5 projects global sea level to be more than 50% higher (26-98 cm) than the old projections (18-59 cm) when comparing similar emission scenarios and time periods. The increase in AR5 sea level projections results from improved modelling of land-ice contributions. Substantial progress in the assessment of extreme weather and climate events has also been made since the AR4 as models now better reproduce phenomena like the El Niño-Southern Oscillation (ENSO; IPCC 2013).

National Projections of Sea Level Rise

The third National Climate Assessment (NCA) was released in May 2014 (Melillo *et al.*), and includes the current best-available science on climate change and sea level rise *at the national scale*. The sea level rise projections in the NCA were informed by the 2012 NOAA report titled *Global Sea Level Rise Scenarios for the United States National Climate Assessment* (Parris *et al.*). This report provides a set of four scenarios of future global sea level rise, as well as a synthesis of the scientific literature on global sea level rise. The NOAA Climate Program Office produced the report in collaboration with twelve contributing authors.[8] The report includes the following description of the four scenarios of sea level rise by the year 2100:

- **Low scenario:** The lowest sea level change scenario (a rise of 8 in (20 cm)) is based on historical rates of observed sea level change.
- **Intermediate-low scenario:** The intermediate-low scenario (a rise of 1.6 ft (0.5 m) is based on projected ocean warming.
- **Intermediate- high scenario:** The intermediate-high scenario (a rise of 3.9 ft (1.2 m)) is based on projected ocean warming and recent ice sheet loss.
- **High scenario:** The highest sea level change scenario (a rise of 6.6 ft (2 m)) reflects ocean warming and the maximum plausible contribution of ice sheet loss and glacial melting.

The Parris *et al*. (2012) report recommends that the highest scenario be considered in situations where there is little tolerance for risk. It also provides steps for planners and local officials to modify these scenarios to account for local conditions. These steps are intended for areas where local sea level rise projections have not been developed. For California, the NRC report (below) provides scenarios that have been refined for use at the local level, and the Coastal Commission, along with the State of California Sea Level Rise Guidance, recommends using the NRC projections rather than the global or national scenarios.

[8] Authors include NOAA, NASA, the US Geologic Survey, the Scripps Institution of Oceanography, the US Department of Defense, the US Army Corps of Engineers, Columbia University, the University of Maryland, the University of Florida, and the South Florida Water Management District.

California-Specific Projections of Sea Level Rise and Best Available Science

In 2012, the National Research Council (NRC) Committee on Sea-Level Rise in California, Oregon and Washington (NRC Committee) released a report, *Sea-Level Rise for the Coasts of California, Oregon, and Washington: Past, Present, and Future*. This report provides an examination of global and regional sea level rise trends and projections of future sea level. It is considered the best available science on sea level rise for California.

To produce global sea level rise projections, the Committee used the basic scenarios that are the foundation of the IPCC AR4 climate projections and earlier climate studies for California. These scenarios were used to model steric changes in global sea level (thermal expansion or contraction), as well as changes in the amount of ocean water due to melting of land-based ice on Greenland, Antarctica, and other land-based glaciers and ice caps. Table A-1 shows the NRC projections for *global* sea level rise.

Table A-1. Recent Global Sea Level Rise Projections for 2000 to 2100

Time Period	NRC 2012 (English)		NRC 2012 (Metric)	
	Projection	Range	Projection	Range
2000 – 2030	5 ± 1 in	3 – 9 in	14 ± 2 cm	8 – 23 cm
2000 – 2050	11 ± 1 in	7 – 19 in	28 ± 3 cm	18 – 48 cm
2000 – 2100	33 ± 4 in	20 – 55 in	83 ± 11 cm	50 – 140 cm

Source: NRC 2012

In addition to the global sea level rise projections, the NRC Committee developed regional/West Coast projections based on the local steric and wind conditions (estimated by using down-scaled global climate models (GCMs), extrapolation of land-ice contributions, and estimates of vertical land motion. The report provides several sets of sea level rise amounts expected by the years 2030, 2050, and 2100 for several locations and regions in California. These include:

- Sea level rise "ranges" for north and south of Cape Mendocino
- Sea level rise "ranges" for San Francisco, Los Angeles, Newport, OR, and Seattle, WA
- Sea level rise "projections" for San Francisco, Los Angeles, Newport, OR, and Seattle, WA

The high and low sea level rise amounts for the "ranges" are based on the A1FI and B1 emission scenarios, respectively. The "projections" (with a standard deviation indicated) are based on the A1B emissions scenario[9]. A subset of these ranges and projections is included in Table A-2. Figure A-3 displays the A1B projections for Los Angeles and San Francisco overlaid on the "ranges" for south of Cape Mendocino. The NRC Report does not provide a California community for the North of Cape Mendocino "projection" so, in addition to the range, the "projection" for Newport, Oregon is provided as a general representation for the North of Cape Mendocino region.

[9] The IPCC A1B scenario assumes similar economic and population growth patterns but with a more balanced energy approach of both fossil-intensive and non-fossil sources.

Table A-2. Regional Sea Level Rise Ranges and Projections (NRC 2012). Ranges and projections with IPCC scenario indicated.

Time Period*	North of Cape Mendocino[10]		South of Cape Mendocino	
	Range: (B1-A1FI scenario)	Projection: Newport, OR (A1B scenario)	Range: (B1-A1FI scenario)	Projection: Los Angeles, CA (A1B scenario)
by 2030	-2 – 9 in (-4 – +23 cm)	3 ± 2 in (7 ± 6 cm)	2 – 12 in (4 – 30 cm)	6 ± 2 in (15 ± 5 cm)
by 2050	-1 – 19 in (-3 – + 48 cm)	7 ± 4 in (17 ± 10 cm)	5 – 24 in (12 – 61 cm)	11 ± 4 in (29 ± 9 cm)
by 2100	4 – 56 in (10 – 143 cm)	25 ± 11 in (63 ± 28 cm)	17 – 66 in (42 – 167 cm)	37 ± 10 in (93 ± 25 cm)

* Relative to the year 2000

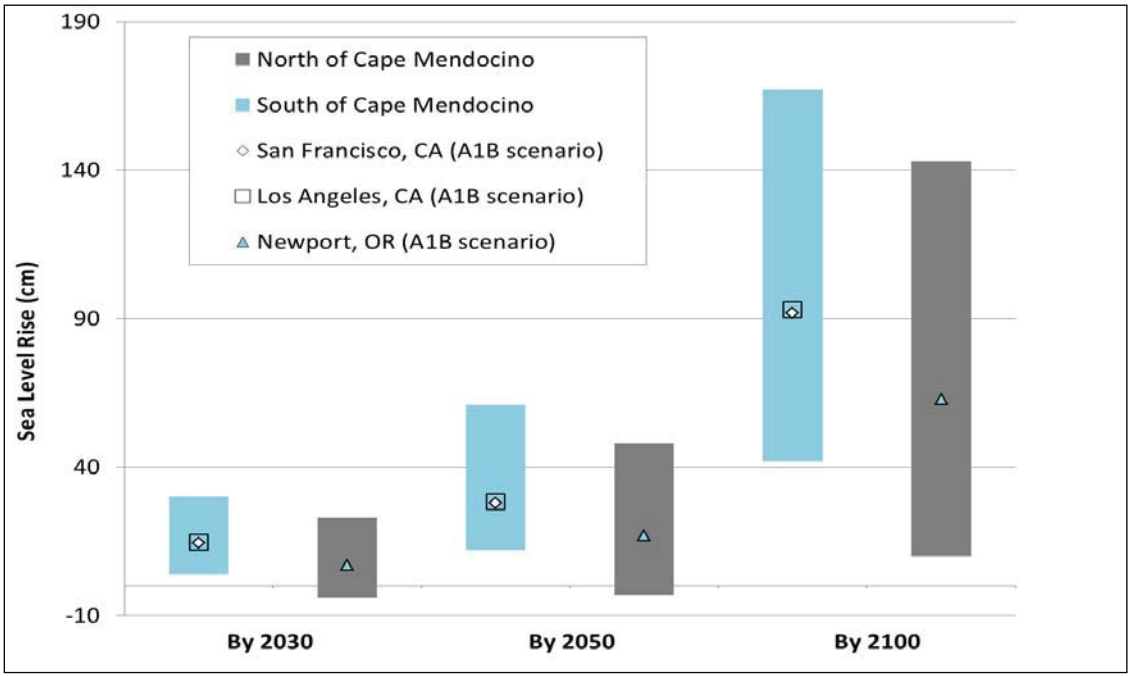

Figure A-3. NRC 2012 sea level rise ranges bounded at the low end by the B1 scenario and by the A1FI scenario at the high end. The points refer to projections based on the A1B scenario.

[10]The NRC Committee divided the Pacific into two regions, north and south of Cape Mendocino, due to differences in tectonics that occur at this point. North of Cape Mendocino, land is rising as ocean plates descend below the North American plate at the Cascadia Subduction Zone. South of Cape Mendocino, the coast is sinking (NRC 2012, p. 3). Humboldt Bay has not experienced the regional uplift that characterizes most of the coast north of Cape Mendocino, and instead has shown the highest subsidence recorded for the California coast. As a result, the projections for north of Cape Mendocino may not be appropriate for use in or near Humboldt Bay and the Eel River Estuary.

Figure A-4. Location of Cape Mendocino

The NRC Committee gave different sea level rise ranges for north and south of Cape Mendocino because it identified distinctly different land level changes in the two regions (Figure A-4). The area north of Cape Mendocino is experiencing significant uplift of about 0.059 to 0.118 in/yr (1.5 to 3 mm/yr), which the Committee attributed to plate movement along the Cascadia Subduction Zone (NRC 2012, p. 93). In contrast, the coast south of Cape Mendocino is dropping at an average rate of about 0.039 in/yr (1 mm/yr) (NRC 2012, p. 93). The measurements of land subsidence south of Cape Mendocino vary widely, from -0.146 in/yr to +0.024 in/yr (-3.7 mm/yr to +0.6 mm/yr) (NRC 2012, p. 93), with slightly greater subsidence in southern California than in Central California.[11] The NRC Committee noted that the uplift being experienced along the Cascadia Subduction Zone may reverse during a fault rupture or earthquake of magnitude 8.0 or greater along the Cascadia Subduction Zone. The NRC report notes that during such an earthquake, coastal areas could experience sudden vertical land motion, with uplift in some locations and subsidence as much as 6.6 ft (2 m) in other locations (NRC 2012). Despite the potential for rapid reversibility of much of the coastal uplift north of Cape Mendocino, the "ranges" for north of Cape Mendocino incorporate land uplift.

In contrast to the vertical uplift occurring throughout the majority of the area north of Cape Mendocino, Humboldt Bay's North Spit and the Eel River Estuary is subsiding and experiencing the highest rate of sea level rise in the state: a rate of 18.6 in (47 cm) over the last century (NOAA 2013). Therefore, the OPC Science Advisory Team recommends making modifications to NRC's sea level rise projections for North of Cape Mendocino based on tide gauge readings for Crescent City and Humboldt Bay, with intermediate values for the areas between them (OPC 2013, p. 11).[12] Please see *Humboldt Bay: Sea Level Rise Hydrodynamic Modeling, and Inundation Vulnerability Mapping* (Northern Hydrology and Engineering 2015) for additional information on sea level rise projections for the Humboldt Bay region.

For the area south of Cape Mendocino, the NRC report provides a range of future sea level rise for the entire region, and ranges and projections for both San Francisco and Los Angeles. The

[11] Personal Communication to staff from Anne Linn, NRC Study Director (August 1, 2012)

[12] A three-member subcommittee of the OPC Science Advisory Team (OPC-SAT) advised using the NRC projections, without modification, for all California locations except between Humboldt Bay and Crescent City (OPC 2013, p. 10).

ranges for both San Francisco and Los Angeles match ranges for the south of Cape Mendocino to within a few millimeters. Because of this close match, and because the NRC report does not indicate what portion of the coast would most appropriately use either the San Francisco or Los Angeles projections, using the city values instead of the regional values is not necessary. The Ocean Protection Council Science Advisory Team recommends using the sea level rise amount for south of Cape Mendocino for the entire region, stating, "we do not believe that there is enough certainty in the sea level rise projections nor is there a strong scientific rationale for specifying specific sea level rise values at individual locations along California's coastline" (OPC 2013, p. 10).

The Coastal Commission recommends that the high and low "ranges" for north and south of Cape Mendocino—along with one or more intermediate values—be considered in all relevant local coastal planning and coastal development permitting decisions. The NRC "projections" may serve as intermediate values where appropriate.

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Appendix B

Developing Local Hazard Conditions Based on Regional or Local Sea Level Rise Using Best Available Science

This Appendix provides technical information regarding how to determine local hazard conditions for sea level rise planning efforts. This process is described more broadly as Steps 1-3 in Chapters 5 and 6 in this document, and includes determining a range of sea level rise projections and analyzing the physical effects and possible resource impacts of sea level rise hazards.

Water level varies locally, so this analysis must be performed on a regional or site specific basis, and applicants and planners should prioritize obtaining data or conducting research at the correct geographical scale. The 2012 National Research Council (NRC) report is considered the best available science on California's regional sea level rise, and the Commission recommends using it when sea level rise projections are needed. Equivalent resources may be used by local governments and applicants provided that the resource is peer-reviewed, widely accepted within the scientific community, and locally relevant.[99]

Much of the research by the Intergovernmental Panel on Climate Change (IPCC) and others, and even the material in the 2012 NRC Report, has focused on global and regional changes to mean sea level. However, the coast is formed and changed by local water and land conditions. Local tidal range influences where beaches, wetlands and estuaries will establish; waves and currents are major drivers of shoreline change; and storms and storm waves are often the major factors causing damage to coastal development. It is local conditions that influence beach accretion and erosion, storm damage, bluff retreat, and wetland function.

Local water levels along the coast are affected by local land uplift or subsidence, tides, waves, storm waves, atmospheric forcing, surge, basin-wide oscillations, and tsunamis. Some of these factors, such as tides and waves, are ever-present and result in ever-changing shifts in the local water level. Other drivers, such as storms, tsunamis, or co-seismic uplift or subsidence, are episodic but can have important influences on water level when they occur. The following section discusses these factors in the context of sea level rise and how to incorporate them into planning and project analysis.

In most situations, high water will be the main project or planning concern. For wetlands, the intertidal zone between low and high tides will be of concern, while in some special situations, such as for intake structures, low water might be the main concern. In situations where low water is the concern, current low water is likely to be the low water planning condition and there may be no need to factor future sea level rise into those project or planning situations. In most other situations, hazards analyses will need to account for sea level rise. The following box identifies some of the key situations in which it may be important for coastal managers and applicants to consider sea level rise during project review.

[99] This appendix is written in such a way that it complements the materials from the 2012 NRC Report, which is currently considered the best available science on sea level rise in California. As new reports are issued in the future, Commission staff will assess whether they should be considered the best available science and update the approaches or terminology in this Appendix accordingly.

General situations needing sea level rise analysis include when the project or planning site is:

- Currently in or adjacent to an identified floodplain
- Currently or has been exposed to flooding or erosion from waves or tides
- Currently in a location protected from flooding by constructed dikes, levees, bulkheads, or other flood-control or protective structures
- On or close to a beach, estuary, lagoon, or wetland
- On a coastal bluff with historic evidence of erosion
- Reliant upon shallow wells for water supply

For situations where future sea level conditions will be important for the analyses of hazards or resource impacts, the following sections are provided as guidance for determining local hazards. Figure B-1 shows the general progression for going from global sea level projections to the possible consequences or impacts that can result from local water levels.

The following information provides details about how to develop sea level rise projections that can be used for specific time periods and geographic areas. It then provides guidance on using these temporally- and regionally-appropriate sea level rise projections to determine future tidal elevations and inundation, future still water, future shoreline change and erosion, potential flooding, wave impacts and wave runup, and flooding from extreme events.

Most of these analyses must occur sequentially. Sea level rise is used to determine changes in tidal conditions, and tidal conditions are combined with future surge, El Niño Southern Oscillation (ENSO) events, and Pacific Decadal Oscillations (PDOs) to estimate local still water. Changes in the frequencies of still water levels will in turn affect erosion rates, and the amount of erosion will affect future wave impacts, runup and flooding.

To be consistent with other sections, these different efforts are presented as Steps, with a discussion of how to accomplish each and the expected outcome. Depending upon the planning or project concerns and required analysis, it may not be necessary to proceed step-by-step and readers should use their judgment as to which items are relevant to their concerns. For example, if the concern is about runup on a non-erosive slope due to an increase in the still water level of 5.5 ft (1.7 m), the guidance on wave runup analysis may be all that is necessary.

Step 1 – Develop temporally- and spatially-appropriate sea level rise projections
Step 2 – Determine tidal range and future inundation
Step 3 – Determine still water level changes from surge, El Niño events and PDOs
Step 4 – Estimate beach, bluff, and dune change from erosion
Step 5 – Determine wave, storm wave, wave runup, and flooding conditions
Step 6 – Examine potential flooding from extreme events

A Note on Hydrodynamic Models versus "Bathtub Fill" Models

It is important to be aware of the differences between a so-called "bathtub fill" model and hydrodynamic models, and the related pros and cons of each for analysis of sea level rise impacts. In general, "bathtub fill" refers to those models that analyze flooding or inundation based solely on elevation. In other words, if sea level is projected to rise 3 ft (1 m), thereby increasing flooding/inundation from a current elevation of +10 ft (3 m) to +13 ft (4 m), these models will, in general, flood everything below the +13 ft (4m) elevation. The modeling does not take into consideration whether the new flood areas are connected to the ocean, nor does it consider how the changes to the water level will change wave propagation or overtopping of flood barriers. This is a significant oversimplification of the processes involved in flooding, but it provides value in allowing individuals to gain a broad view of the general areas that could be impacted by sea level rise without requiring a great deal of technical information.

Conversely, hydrodynamic modeling takes into account the details of local development patterns and the characteristics of waves and storms, and can therefore provide a much better understanding of local sea level rise impacts than is possible from "bathtub fill" models. In particular, hydrodynamic models take into account factors that alter flooding and inundation patterns and impacts. Such factors may include the extent and orientation of development – for example, roadways and linear features that tend to channelize water flows, and buildings or flood barriers that can block and divert flows – as well as the conditions that contribute to flooding and inundation, such as wave conditions, flow velocities, the extent of overtopping, and so on. Although the initial development of the modeling grid that is used to depict the community development patterns can be quite time-consuming to create and the model output will change with differing grid designs (Schubert and Sanders 2012), once the grid is developed, hydrodynamic modeling can be used to better characterize areas of flooding and to distinguish areas of concentrated flooding from those areas that may experience small amounts of flooding only during peak conditions (Gallien *et al.* 2011, 2012).

Significantly, many of the analyses described in this Appendix are the kinds of analyses that go beyond "bathtub fill" modeling to include the hydrodynamic factors that help to specify the more location-specific impacts for which planners should prepare.

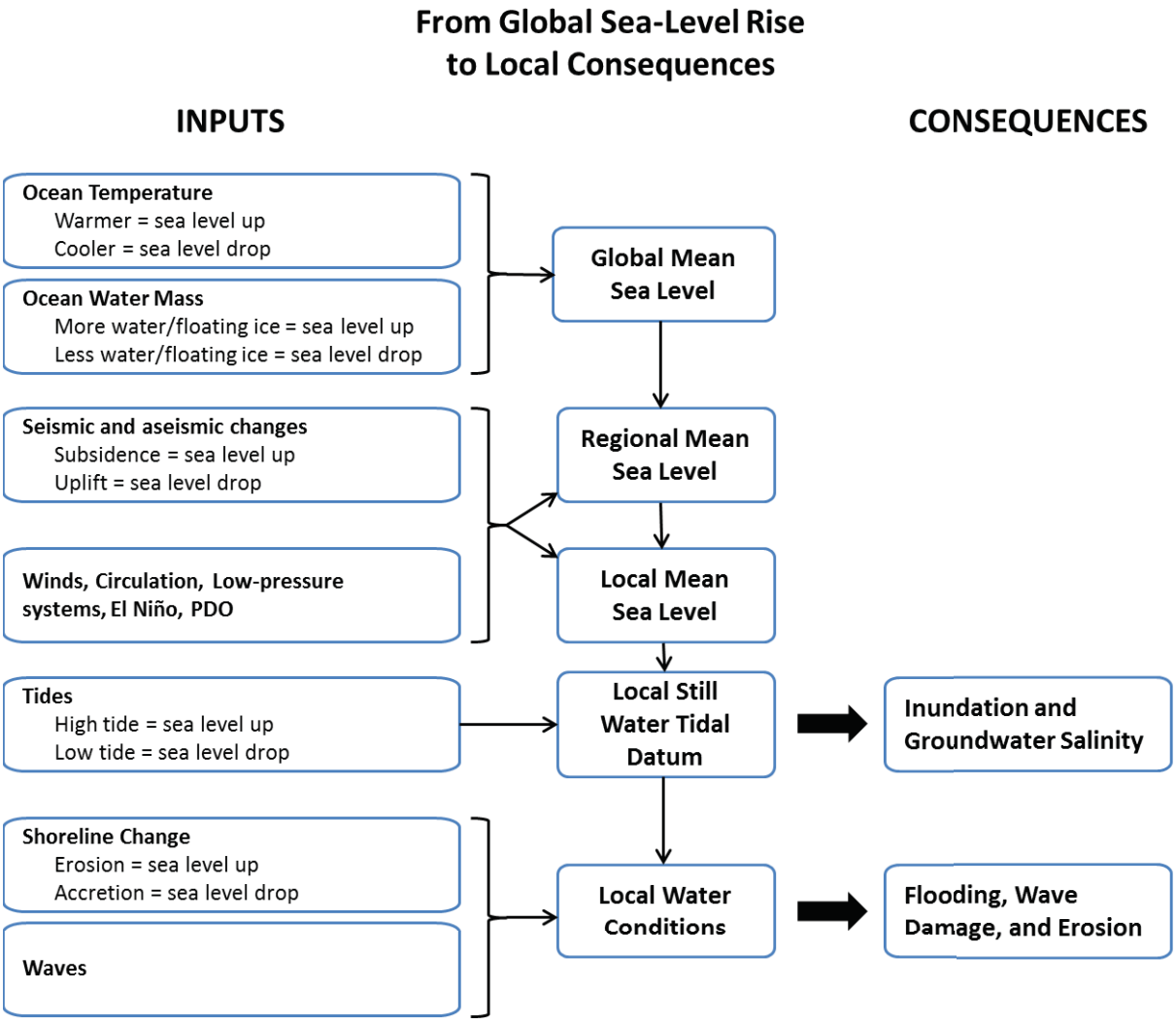
From Global Sea-Level Rise
to Local Consequences
INPUTS
CONSEQUENCES
Ocean Temperature
Warmer = sea level up
Cooler = sea level drop
Ocean Water Mass
More water/floating ice = sea level up
Less water/floating ice = sea level drop
Global Mean Sea Level
Seismic and aseismic changes
Subsidence = sea level up
Uplift = sea level drop
Regional Mean Sea Level
Winds, Circulation, Low-pressure systems, El Niño, PDO
Local Mean Sea Level
Tides
High tide = sea level up
Low tide = sea level drop
Local Still Water Tidal Datum
Inundation and Groundwater Salinity
Shoreline Change
Erosion = sea level up
Accretion = sea level drop
Waves
Local Water Conditions
Flooding, Wave Damage, and Erosion

Figure B-1. General process for translating global sea level rise to local consequences

Step 1 – Develop temporally- and spatially-appropriate sea level rise projections

a. Determine appropriate planning horizon or expected project life

The first step in a sea level rise analysis is to determine the appropriate planning horizon based on the expected life of the project. The longer the life of a project or planning horizon, the greater the amount of sea level rise the project or planning area will experience.

Local governments should select their planning horizons to evaluate a broad range of planning concerns. Planning horizons could address the 20-year time period that is typical for *General Plan* updates as well as the long-range planning that is necessary for infrastructure and new development. The 20-year planning horizon may help identify areas within the coastal zone that are now or will soon be vulnerable to sea level rise related hazards as an aid for focusing adaptation planning on the areas of greatest need. Local Coastal Program (LCP) planning will likely use multiple planning horizons and undertake hazards analyses for multiple time periods, multiple sea level rise projections, or both.

At the project level, the LCP may provide insight into the time period that should be considered for the expected project life. At present, LCPs typically provide only a single standard (if any) for the expected life of a structure or development, such as 50, 75, or 100 years. Future LCPs and LCP Amendments (LCPAs) may find it useful to provide greater guidance on expected project life, with differentiations among major development or use classifications. For example, a general range may be chosen based on the type of development such that temporary structures, ancillary development, amenity structures, or moveable or expendable construction should identify a relatively short expected life of 25 years or less. Residential or commercial structures, which will be around longer, should choose a time frame of 75 to 100 years to consider. A longer time frame of 100 years or more should be considered for critical infrastructure like bridges or industrial facilities or for resource protection or enhancement projects that are typically meant to last in perpetuity.

For projects with long lead times, the analysis of impacts from sea level rise should use the projections for the time period when the development will be in use, rather than the current period because the trajectory of future sea level rise is not expected to be linear. For example, a project built today will experience less sea level rise over a 50-year lifetime (about 24 in (61 cm) using the higher projections for south of Cape Mendocino) than the same project if it were built in the year 2050 (about 40 in (101 cm), using the higher projections for south of Cape Mendocino). Thus, it is important to understand the anticipated project life of a structure and the associated planning horizon before starting an analysis for sea level rise concerns.

As explained in Chapters 5 and 6, the point of this step is not to specify exactly how long a project will exist (and be permitted for), but rather to identify a project life timeframe that is typical for the type of development in question so that the hazard analyses performed in subsequent steps will adequately consider the impacts that may occur over the entire life of the development.

b. Project sea level rise for years other than 2030, 2050, and 2100

At present, the 2012 NRC report provides the best available science for regional sea level rise projections from the year 2000 to 2030, 2050, and 2100. For sea level rise projections for years within a few of those used in the NRC projections, the 2030, 2050, and 2100 projections can be used. However, for years that are not close to these years, sea level rise projections should be interpolated from the projections. Two methods are recommended for establishing a projection value for a specific year: 1) conduct a linear interpolation[100], or 2) use the "best fit" equations that are provided below. At this time, both are acceptable for Coastal Commission purposes.

1. ***Linear Interpolation:*** One method for establishing a sea level rise projection for a specific year is linear interpolation between two known or given projections. The most immediate time periods before and after the desired time period should be used. For example, for a proposed project south of Cape Mendocino with an expected life until the year 2075, the upper range for the sea level rise projections closest to this time period are 24 in (61 cm) for Year 2050, and 66 in (167 cm) for Year 2100.

$$\mathrm{SLR}_{2075} = \mathrm{SLR}_{2050} + [\mathrm{SLR}_{2100} - \mathrm{SLR}_{2050}] * \frac{2075 - 2050}{2100 - 2050}$$

$$\mathrm{SLR}_{2075} = 24\ \mathrm{in} + [66\ \mathrm{in} - 24\ \mathrm{in}] * \frac{25\ \mathrm{years}}{50\ \mathrm{years}}$$

$$\mathrm{SLR}_{2075} = 45\ \mathrm{in} = 114\ \mathrm{cm}$$

2. ***"Best-Fit" Equation:*** Figure B-2 illustrates smoothed curve fits for the high and low ranges of expected sea level rise from 2012 NRC report, along with several local projections. As seen from these curves, a linear interpolation between any two points on the curves would be slightly higher than a projection that is represented by the curve itself. A second option that can be used to estimate sea level rise projections for years other than years 2030, 2050, and 2100 that avoids this slight discrepancy is to use one of the following quadratic equations that represent the "best fit" for each of the above sea level rise curves. These equations provide sea level rise in centimeters. If English units are desired, the projections will need to be converted using 1 cm = 0.0328 ft, or 1 cm = 0.394 in.

[100] Linear interpolation is a method for filling in gaps in data or information that assumes that two known data points that bound the unknown point can be connected with a straight line. The missing information is estimated through reference to this line. The example in the text provides an example of the mathematical steps for linear interpolation.

Equations for Sea Level Rise Projections, based on values from the 2012 NRC Report

North of Cape Mendocino

- [*Upper Range*] Sea Level Change (cm) $= 0.0094t^2 + 0.4868t$ (Equation B1)
- [*Lower Range*] Sea Level Change (cm) $= 0.0033t^2 - 0.2257t$ (Equation B2)

South of Cape Mendocino

- [*Upper Range*] Sea Level Change (cm) $= 0.0093t^2 + 0.7457t$ (Equation B3)
- [*Lower Range*] Sea Level Change (cm) $= 0.0038t^2 + 0.039t$ (Equation B4)

Where "t" is the number of years after 2000

For example, if the proposed project were south of Cape Mendocino, with an expected life of 75 years, use Equation B3, with t = 75 (*i.e.*, Year 2075):

$$\mathrm{SLR}_{2075} = (0.0093 \times 75^2) + (0.7457 \times 75)$$

$$\mathrm{SLR}_{2075} = 52 + 56 = 108 \text{ cm} = 43 \text{ in}$$

The sea level projection estimated using the "best-fit" equation is slightly less than the estimation based on linear interpolation because the NRC's sea level curves, shown in Figure B-2, are concave upward (sea level rise is expected to accelerate over the 21st Century). A line between any two points on the curve will always be slightly higher than the curve itself.

As noted previously, either of the two methods is acceptable for estimating sea level rise for a year that has not been provided in the NRC Report.

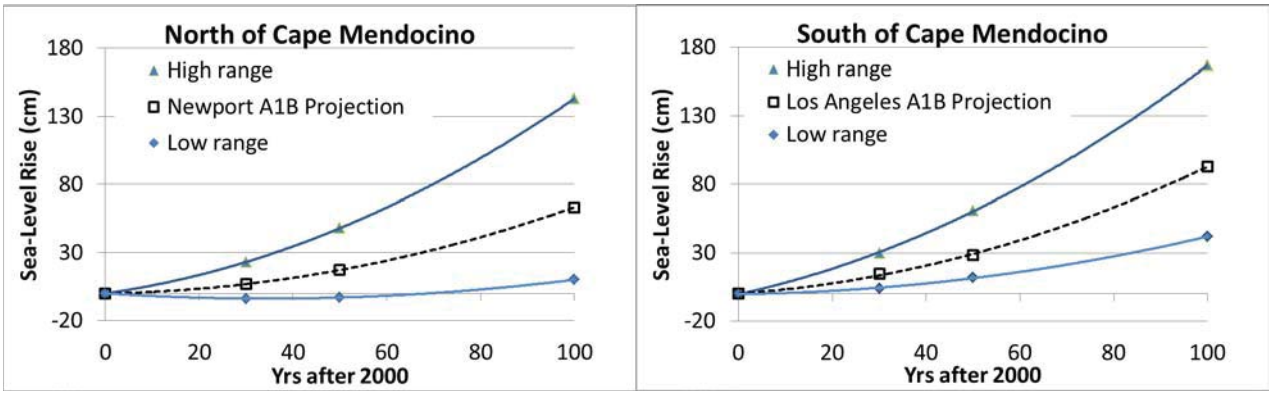

Figure B-2. Ranges of sea level rise based on 2012 NRC report. The NRC report used the IPCC (2007) A1FI scenario to represent the high range, and the B1 scenario to represent the low range. North of Cape Mendocino, Newport, OR, provides a mid-range A1B scenario projection and south of Cape Mendocino, Los Angeles, CA, provides a mid-range A1B scenario projection.

c. Ranges of sea level rise projections that do not start at the year 2000

The NRC sea level rise projections use the year 2000 as the base year. Since there has been little, if any, measureable rise in sea level since 2000 for most locations in California (Bromirski *et al.* 2011; NOAA 2013), there is little reason or justification for adjusting sea level rise projections from the year 2000 baseline to a more current date when analyzing projects with start dates prior to about Year 2015 or 2020. However, the latent sea level rise might occur quickly, providing sea level conditions consistent with the future projections. Thus, when analyzing sea level rise impacts for projects that are proposed to begin development in the near future and to exist for a limited lifetime, there is no need to adjust the 2012 NRC projections for a different project starting year or to account for the current lack of significant sea level change from the year 2000 baseline.

Conversely, if the needed sea level rise value is the range of sea level that might be experienced over a future time period, as might be used for planning a wetland restoration project, then adjustments to the starting point for sea level rise projections may be necessary. In such a case, this sea level range can be developed by interpolating the sea level projections for the starting and ending years (using the processes above for years other than 2030, 2050, and 2100), and obtaining the difference in sea level by subtracting these two. For example, if a restoration project is proposed to be designed to take into account the sea level rise that will occur from years 2040 to 2060, use Equations B1, B2, B3, or B4 to get $SLR_{t1=2040}$ and $SLR_{t2=2060}$. Then, subtract SLR_{2040} from SLR_{2060} to get the range of sea level rise that is anticipated from years 2040 to 2060.

d. Sea level rise projections beyond year 2100

Sea level rise is expected to continue well past the year 2100, despite the termination of most projections at that year in the scientific literature. However, the uncertainty associated with any projections for sea level grows significantly as the time period increases and there are large uncertainties in projections for sea level rise in the year 2100 and beyond. Despite such uncertainty, long-term planning and projects requiring long lead times or large capital expenditures need to consider conditions that might occur in the next 100 or more years in order to analyze potential hazards.

At this time, there are no studies that specifically address projections of sea level rise for California beyond the year 2100. The NRC projections stop at Year 2100 and provide no guidance for extrapolation of the range of sea level rise projections past that time. The equations provided above, while most appropriate for interpolation up to 2100, can be used to extrapolate sea level rise for a few years beyond 2100. However, for projections beyond about years 2105 or 2110, alternative methods should be considered for developing sea level rise projections. Options for developing sea level rise projections for years beyond 2100 include:

1. Use the NRC projections for 2050 and 2100 to develop a linear trend beyond Year 2100.
2. Use sea level rise rates that have been developed in recent years, some of which are provided in Table B-1.

3. Interpolate between the NRC projections, and one of the reports that provides projections of global sea level rise for years 2200 or 2300 (some of which are listed in Table B-2).

None of these options will provide sea level rise projections that have a confidence similar to the NRC projections. Eventually, there may be regionally appropriate projections for sea level into the 22nd and 23rd centuries. Until then, simplifying assumptions might be necessary for analysis that goes into these time periods. It is clear that sea level will continue to rise past 2100, and any effort to look beyond the year 2100 will be better than using projections of sea level rise for 2100 as the upper limit of what might happen beyond that time. Nonetheless, it is critical that long-range planning efforts and projects with long design lives include provisions to revisit SLR hazards periodically, and to make adjustments as new science becomes available.

Table B-1. Range of Global Sea Level Rise (*from Nicholls et al. 2011*)

Source	Methodological Approach	Sea level rise ft/century (m/century)
Rahmstorf 2007	Semi-empirical projection[a]	1.6 – 4.6 (0.5 – 1.4)
Rohling *et al.* 2008	Paleo-climate analogue	2.6 – 7.9 (0.8 – 2.4)
Vellinga *et al.* 2008	Synthesis[a]	1.8 – 3.6 (0.55 – 1.10)
Pfeffer *et al.* 2008	Physical constraints analysis[a]	2.6 – 6.6 (0.8 – 2.0)
Kopp *et al.* 2009	Paleo-climate analogue	1.8 – 3.0 (0.56 – 0.92)
Vermeer and Rahmstorf 2009	Semi-empirical projection[a]	2.5 – 6.2 (0.75 – 1.90)
Grinsted *et al.* 2009	Semi-empirical projection[a]	2.4 – 5.2 (0.72 – 1.60)[b]

[a] For the 21st Century
[b] For the best paleo-temperature record.

Table B-2. Projections of Global Sea Level Rise Beyond Year 2100

Projection Scenario[a]	Sea level rise for 2300, referenced to 2000 (Schaeffer *et al.* 2012) ft (m)	2300 Sea level rise rate (Schaeffer *et al.* 2012) in/yr (mm/yr)	Sea level rise for 2500, referenced to 2000 (Jevrejeva *et al.* 2012) ft (m)
RCP4.5	7.0 – 17.3 (2.12 – 5.27)	0.24 – 0.74 (6 - 20)	2.4 – 14.1 (0.72 – 4.3)
RCP3PD	3.9 – 10.1 (1.18 – 3.09)	0.04 – 0.35 (1 - 9)	0.4 – 5.7 (0.13 – 1.74)
RCP6			3.4 – 19.0 (1.03 – 5.79)
RCP8.5			7.4 – 37.8(2.26 – 11.51)
Stab 2°C	5.1 – 13.2 (1.56 – 4.01)	0.16 – 0.55 (4 – 14)	
Merge400	2.8 – 7.7 (0.86 – 2.36)	-0.08 – 0.12 (-2 – 3)	
Zero 2016	2.5 – 6.8 (0.76 – 2.08)	0.04 – 0.24 (1 – 6)	

[a] See referenced reports for details on projection scenarios.

Step 2 – Determine tidal range and future inundation

One of the most basic examinations of changing sea level conditions has been to determine the new intersection of mean sea level or other tidal datums[101] with the shoreline. This is a basic "bathtub" analysis since it looks only at the expansion of areas that will be inundated (*i.e.*, regularly submerged under water) or subject to tidal or wave action. For example, future subtidal levels would be the current subtidal limit plus projected regional mean sea level rise. Future intertidal zones would be bounded by the future higher high tide level (current higher high water plus projected regional sea level rise) and future lower low tide levels (current lower low water plus projected regional sea level rise).[102] For some projects, such as wetland restoration, the identification of future inundation zones may be the only sea level analysis needed for project evaluation. However, if the shoreline is eroding, the location of this elevation would need to also incorporate the rate of erosion. So, if the shoreline is expected to erode due to increased wave attack, not only will the intertidal zone move up in elevation, it will be both higher than and inland of the current zone.

Future Water *Elevation* = Current Tidal Datum + Projected Sea Level Rise

OR

Future Water *Location* = Intersection of Future Water Elevation with Future Shore Location

Future water location will extend to the new inundation elevation on the future shoreline. On beaches with a gradual slope, this can move the inundation location significantly inland, based on the geometric conditions of the beach. (This type of analysis is often called the Bruun Rule). On a stable beach with a slope of 1:X (Vertical:Horizontal), every foot of vertical sea level rise will move the inundation area horizontally X feet inland. For a typical 1:60 beach, every foot of sea level would move the inundation zone inland by 60 ft. If the beach is eroding, the loss due to erosion will add to the loss resulting from inundation.

Figure B-3 shows the influence of tides and sea level rise on low-wave energy beaches. Table B-3 provides some useful resources for inundation studies. Local Tidal Elevations are available from tide gauges maintained by NOAA. Where there are no nearby gauges, NOAA recommends the VDatum software.

[101] Tidal datums are based on the latest National Tidal Datum Epoch (NTDE) published by NOAA and are the mean of the observed sea levels over a 19-year period. The latest published epoch is 1983-2001. This tidal epoch can be considered equivalent to the year 2000 baseline for the NRC projections.

[102] Historical trends of high and low tide have changed differently than mean sea level (Flick *et al.* 2003). Based on historical trends, the changes to various tidal elements are likely to track closely with, but not identically with, changes to mean sea level. The future variability of changes to the tidal components, compared with changes to mean sea level will normally fall within the uncertainty for sea level rise projections and can be disregarded in almost all situations. As this phenomenon of tidal change is better understood and can be modeled, it may be appropriate in the future to include the changes in tidal components into the analysis of inundation and various water level projections.

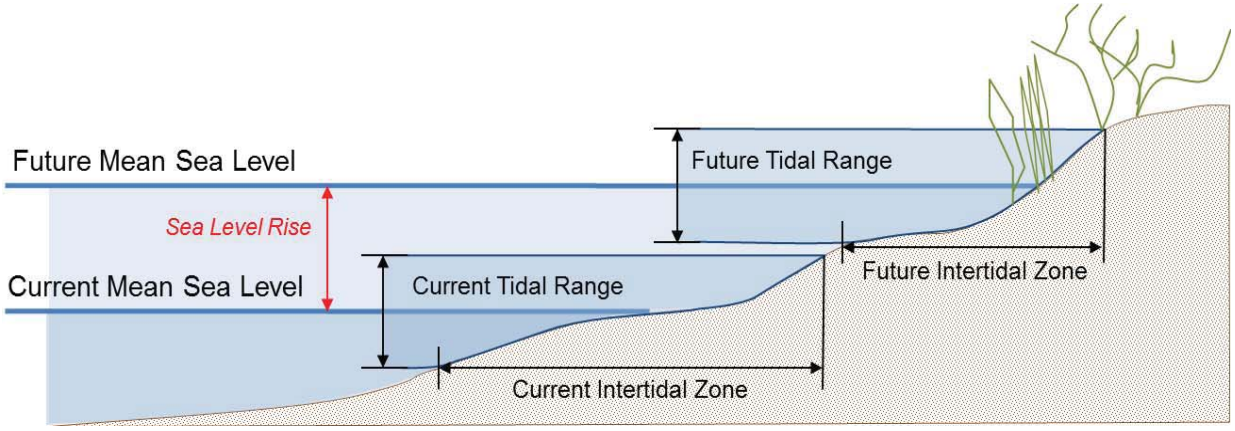

Figure B-3. Sea level rise and changes to tide range and intertidal zone. (*Source: L. Ewing, 2013*).

Table B-3. General Resources for Inundation Studies

Resource	Description	Link
Aerial Photographs	Useful for general information on shoreline trends; ortho-rectified photos can help quantify trends.	California Coastal Records Project, www.californiacoastline.org; Huntington Library; Local Libraries
LIDAR	Fairly detailed topography providing GIS layers for current conditions and comparable with LIDAR data sets for temporal changes.	NOAA Digital Coast, http://coast.noaa.gov/digitalcoast/data/coastallidar
Topographic Maps	Useful for basemaps to overlay site changes; often not at a scale to distinguish small changes in inundation or tidal action.	USGS Map Center, http://www.usgs.gov/pubprod/maps.html
NOAA Sea Level Rise and Coastal Flooding Impacts Viewer	Useful to show changes in water level location if there are no changes in the land due to erosion.	NOAA Digital Coast, http://coast.noaa.gov/digitalcoast/tools/slr/
NOAA Tidal Data	Measured and predicted tidal components for locations along the open coast and in bays.	NOAA Center for Operational Oceanographic Products and Services, http://tidesandcurrents.noaa.gov/
NOAA Technical Report NOS 2010-01: *Technical Considerations for use of Geospatial Data in Sea Level Change Mapping and Assessment*	Provides technical guidance to agencies, practitioners, and decision makers seeking to use geospatial data to assist with sea level change assessments.	NOAA National Ocean Service http://www.tidesandcurrents.noaa.gov/publications/tech_rpt_57.pdf

VDatum Software	A Vertical Datum Transformation program that allows users to transform geospatial data among various geoidal, ellipsoidal and tidal vertical datums.	NOAA National Ocean Service, http://www.nauticalcharts.noaa.gov/csdl/vdatum_enhancements.html
Cal-Adapt – Exploring California's Climate	Shows coastal areas that may be threatened by flooding from a 4.6 ft (1.4 m) rise in sea level and a 100-year flood event. Maps were developed using the Pacific Institute SLR Maps and do not now include any influence of beach or dune erosion or existing protective structures.	http://cal-adapt.org/sealevel/
Estimating Sea Level for Project Initiation Documents	Provides guidance on converting tidal datums and predicting future sea levels.	Caltrans Office of Land Surveys, http://www.dot.ca.gov/hq/row/landsurveys/SurveysManual/Estimating_Sea_Level_v1.pdf

Outcome from Step 2: *Provide information on the projected changes to the tidal range and future zones of inundation. For locations without any influence from erosion, storm surge, or wave energy, the identification of new inundation areas may be sufficient for project analysis and planning efforts. This projected new inundation area may also be useful for anticipating the likely migration of wetlands and low-energy water areas or as input for analysis of changes to groundwater salinity. For most open coast situations, this information will be used to inform further project planning and analysis that examines erosion, surge and storm wave conditions.*

Step 3 – Determine still water changes from surge, El Niño events, and PDOs

Estimates of surge, El Niño, and PDO water elevation changes are developed primarily from historical records. There are no state-wide resources for this information, although it may be included in some Regional Sediment Management Plan studies. General guidance on water level changes that can be expected from surge, El Niño events, and PDOs is provided in Table B-4.

> *The remaining discussion provides general information on some of these phenomena. It is provided to acquaint readers to the main issues associated with each phenomenon. Readers with a strong background in ocean-atmospheric conditions may want to skim or skip the rest of this section.*

The Pacific Ocean is a complex system. Sea level in the Pacific Ocean responds to multiple oceanic and atmospheric forcing phenomena, occurring with different intensities and at different temporal and spatial scales. Some phenomena may reinforce each other, while others may act in opposition, reducing the net effect. Scientists and researchers are attempting to identify the

various signals from the multiple phenomena, but these are nascent sciences and there is still much we need to learn.

Regional water levels can be influenced by surge as well as by high and low pressure systems. Surge is a short-term change in water elevation due to high wind, low atmospheric pressure, or both. It is most often associated with East Coast and Gulf Coast hurricanes that can cause up to 15 or 20 ft (4-6 m) or more of short-term water level rise over many miles of the coast. Along the West Coast, storm surge tends to be much smaller, and is rarely a coastal hazard, except in enclosed bays. In southern California, it rarely exceeds 1 ft (0.3 m) and in central California, it rarely exceeds 2 ft (0.6 m). Surge becomes a concern as one of several cumulative factors that cause a temporary rise in sea level. Each rise may be small, but when surge occurs during high tides and/or in combination with storms, it increases the threat of coastal flooding, wave impacts, and erosion.

Two of the more recognized phenomena that affect water temperature in the Pacific are the El Niño-Southern Oscillation (ENSO) and the Pacific Decadal Oscillation (PDO). ENSO cycles, which occur on inter-annual timescales (approximately 2-7 years), not only involve ocean-basin-spanning changes in sea surface temperature (SST) and in the depth of the mixed layer in the Equatorial Pacific, but also drive changes in ocean conditions and atmospheric circulation at higher latitudes. El Niño events result in the transfer of warm surface waters into the normally cool eastern equatorial Pacific, resulting in elevated SST and water levels along much of the west coast of the Americas. El Niños also tend to increase the strength and frequency of winter low pressure systems in the North Pacific. These events can persist for months or years at a time, and strongly influence local and regional sea level. For example, the pulse of warm water from the large 1982-83 El Niño caused water levels along California to be elevated by approximately 0.4-0.7 ft (0.12-0.21 m) for many months, with short-term water elevation peaks up to approximately 1 ft (0.3 m; Flick 1998). The opposite phase of ENSO, characterized by unusually cool SSTs and lower water elevations along the eastern Pacific margin, are called La Niña events. Between El Niños and La Niñas are periods of neutral SST and water elevation changes.

The PDO is an ENSO-like pattern of SST and atmospheric variability occurring over multiple decades. In contrast to ENSO, the PDO is more strongly expressed in the North Pacific than in the tropics. The positive or warm phase of the PDO is associated with unusually warm surface water throughout the eastern North Pacific (along the western US coast), while the negative or cool phase PDO is associated with colder than normal waters. As with the ENSO effects, the warm phase PDO has tended to cause elevated sea levels in the eastern Pacific and along the California coast, while the cool phase of the PDO tends to lower sea level in this region.

The PDO has basin-wide influence. Elevated water levels in one part of the Pacific are often accompanied by lowered water levels elsewhere. The cool phase PDO can result in a drop of water level along the eastern Pacific (western US Coast) and a rise in water level along the western Pacific. Recently, sea level along the western Pacific has been rising about three times faster than the global mean sea level rise rate, due in part to the PDO (Bromirski *et al.* 2011; Merrifield 2011). This does not mean the eastern Pacific will experience sea level rise that is three times faster than the global mean sea level rise when there is the next shift in the PDO, but does show that the PDO can have a major influence on basin-wide and regional sea level.

The above discussion of El Niño and the PDO may suggest that they are well-understood phenomena, with easily anticipated changes in sea level. However, it is important to note that El Niños have varying strengths and intensities, resulting in different sea changes from one event to the next. Also, changes in regional mean sea level along the eastern Pacific have not always shown a strong connection to the PDO cycles. An apparent jump in regional mean sea level occurred after the mid-1970s shift to the warm phase of the PDO, yet the expected continued rise in sea level along the West Coast seems to have been suppressed by other forces. Tide gauge records for the Washington, Oregon, and California coasts have shown no significant inter-annual rise in sea level from 1983 to 2011 (Cayan *et al.* 2008; Bromirski *et al.* 2011; NOAA 2013). Bromirski *et al.* (2011, 2012) postulate that persistent alongshore winds have caused an extended period of offshore upwelling that has both drawn coastal waters offshore and replaced warm surface waters with cooler deep ocean water. Both of these factors could have caused a drop in sea level, canceling out the sea rise that would otherwise be expected from a warm phase PDO signal.

Water level changes from surge, atmospheric forcing, El Niño events and the PDO can occur in combination. The water elevation changes from each factor may be only about 1 ft (0.3 m) or less, but each can cause changes in the water level over a time period of days, months, or a few years – far more rapidly than sea level rise. In combination, they can potentially cause a significant localized increase in water level.

When high water conditions occur in combination with high tides, and with coastal storms, the threat of coastal flooding, wave impacts and erosion also increases. These conditions can be additive, as shown in Figure B-4. Also, these changes in water level will continue to be important to the overall water level conditions along the California coast and they need to be examined in conjunction with possible changes due to regional sea level rise.

As stated earlier, estimates of surge, El Niño and PDO water elevation changes are developed primarily from historical records. There are no state-wide resources for this information, although it may be included in one of the Regional Sediment Management Plans, available for many coastal areas (see http://www.dbw.ca.gov/csmw/). General guidance on water level changes, surge, and El Niño events is provided in Table B-4.

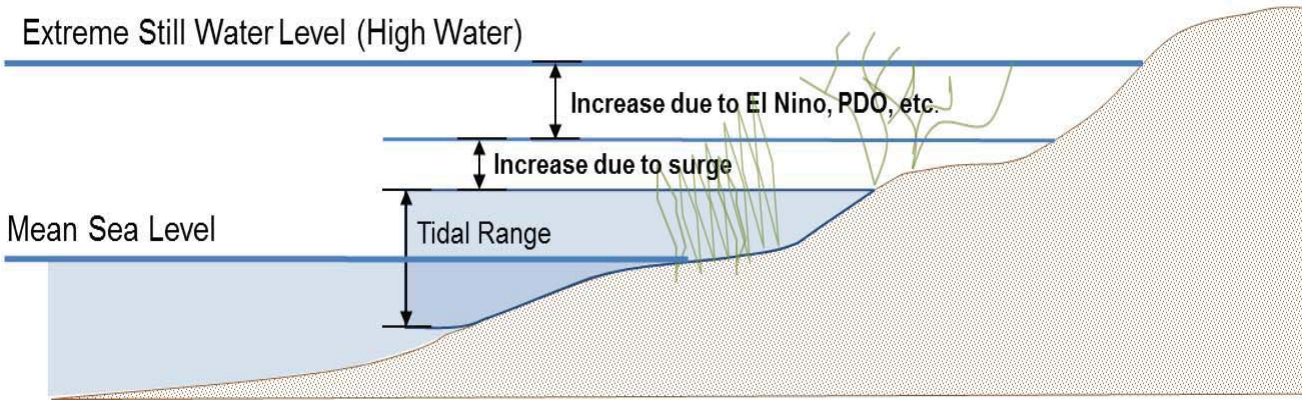

Figure B-4. Changes to extreme still water level due to surge, El Niño events, and PDOs. (*Source: L. Ewing, 2013*).

Table B-4. General Resources for Determining Still Water Elevation, Surge, El Niño events, and PDOs

Resource	Description	Link
NOAA Sea Level Rise and Coastal Flooding Impacts Viewer	Displays potential future sea levels within wetland areas, and provides visualizations for various amounts of sea level rise. For bays and estuaries, it also provides information on inland areas with the potential to flood if existing barriers to water connectivity are removed or overtopped. Communicates spatial uncertainty of mapped sea level rise, overlays social and economic data onto sea level rise maps, and models potential marsh migration due to sea level rise. Maps do not include any influence of beach or dune erosion.	NOAA Digital Coast, http://coast.noaa.gov/digitalcoast/tools/slr/
Pacific Institute Sea Level Rise Maps	Downloadable PDF maps showing the coastal flood and erosion hazard zones from the 2009 study. Data are overlaid on aerial photographs and show major roads. Also available are an interactive online map and downloadable maps showing sea level rise and population and property at risk, miles of vulnerable roads and railroads, vulnerable power plants and wastewater treatment plants, and wetland migration potential.	http://www.pacinst.org/reports/sea_level_rise/maps/ For the 2009 report "The Impacts of Sea Level Rise on the California Coast" visit: http://pacinst.org/publication/the-impacts-of-sea-level-rise-on-the-california-coast/
Cal-Adapt – Exploring California's Climate	Shows coastal areas that may be threatened by flooding from a 4.6 ft (1.4 m) rise in sea level and a 100-year flood event. Maps were developed using the Pacific Institute SLR Maps (see above) and do not now include any influence of beach or dune erosion or existing protective structures.	http://cal-adapt.org/sealevel/
Regional Sediment Management Plans	Plans for regions of the state to identify how governance, outreach and technical approaches can support beneficial reuse of sediment resources within that region without causing environmental degradation or public nuisance.	http://www.dbw.ca.gov/csmw/

***Outcome from Step 3**: Provide estimates of water elevations that can result from surge, El Niño events, and PDOs. When combined with the sea level changes to the tidal range, developed in Step 4, these can provide information on the extreme still water level. For most open coast situations, this information will be used to inform further project analysis and planning that examines erosion, surge and storm conditions.*

Step 4 – Estimate beach, bluff, and dune change from erosion

Predictions of future beach, bluff, and dune erosion are complicated by the uncertainty associated with future waves, storms and sediment supply. As a result, there is no single specific accepted method for predicting future beach erosion. At a minimum, projects should assume that there will be inundation of dry beach and that the beach will continue to experience seasonal and inter-annual changes comparable to historical amounts. When there is a range of erosion rates from historical trends, the high rate should be used to project future erosion with rising sea level conditions (unless future erosion will encounter more resistant materials, in which case lower erosion rates may be used). For beaches that have had a relatively stable long-term width, it would be prudent to also consider the potential for greater variability or even erosion as a future condition. For recent studies that provide some general guidance for including sea level rise in an evaluation of bluff and dune erosion, see, for example, Heberger *et al.* (2009) or Revell *et al.* (2011). Other approaches that recognize the influence of water levels in beach, bluff, or dune erosion can also be used. Table B-5, at the end of this section, provides some resources that can be used for projecting future erosion.

The following sections discuss specific concerns associated with beach, bluff and dune erosion and are provided to acquaint readers to the main issues associated with each system. Readers with a strong background in coastal systems may want to skim or skip the rest of this section.

Beach Erosion

Beach erosion and accretion occur on an on-going basis due to regular variability in waves, currents and sand supply. The movement of sand on and off of beaches is an ongoing process. Along the California coast, periods of gradual, on-going beach change will be punctuated by rapid and dramatic changes, often during times of large waves or high streamflow events.

The overall dynamics of beach change have been described many times.[103] Sand moves on and off shore as well as along the shore. Normal sources of sand to a beach are from rivers and streams, bluff erosion or gullies, and offshore sand sources. Sand leaves a beach by being carried downcoast by waves and currents, either into submarine canyons or to locations too far offshore for waves to move it back onto shore. Beaches are part of the larger-scale sediment dynamics of the littoral cell, and in very simple terms, beaches accrete if more sand comes onto the beach than leaves and beaches erode if more sand leaves than is added. Changes in sand supply are a major aspect of beach change.

Beach changes are often classified as being either seasonal or long-term/inter-annual changes. Seasonal changes are the shifts in beach width that tend to occur throughout the year and are usually reversible. During late fall and winter, beaches tend to become narrower as more high energy waves carry sand away from the beach and deposit it in offshore bars. This is later followed by beach widening as gentler waves again bring sand landward, building up a wider

[103] See for example, Bascom 1980, Komar 1998, and Griggs *et al.* 2005.

dry-sand summer beach. These changes are considered seasonal changes, and if the beach widths return to the same seasonal width each year, then the beach experiences seasonal changes but no long-term or inter-annual changes. If the seasonal beach widths become progressively wider or narrower, these changes become long-term or inter-annual change, and suggest a long-term beach change trend – accretion if the beach is widening and erosion if the beach is narrowing.

If development is at or near beach level, erosion of the beach can expose the development to damage from waves, flooding, and foundation scour. Additionally, waves that hit the coast bring with them vegetation, floating debris, sand, cobbles, and other material which can act like projectiles, adding to the wave forces and flood damage.

At present, approximately 66% of the California beaches have experienced erosion over the last few decades, with the main concentration of eroding beaches occurring in southern California (Hapke *et al.* 2006). This erosion has been due to a combination of diminished sand supplies and increased removal of sand by waves and currents. With rising sea level, beach erosion is likely to increase due to both increased wave energy[104] that can carry sand offshore or away from the beach, and to decreased supply of new sediments to the coast.[105]

There are several factors that will contribute to the effects of sea level rise on seasonal and inter-annual beach change. There will be the changes to the beach due to inundation by rising water levels, as shown in Figure B-5 (see the discussion on inundation earlier in this Appendix for more information on how to determine this change). If the beach cannot migrate inland to accommodate these changes, then the inundation will result in a direct loss or erosion of beach width. This will result in a narrower seasonal beach as well as inter-annual loss of beach.

Seasonal and inter-annual beach conditions will also be affected by changes to waves and sediment supply. Since waves are sensitive to bottom bathymetry, changes in sea level may change the diffraction and refraction of waves as they approach the coast, thereby changing the resulting mixture of beach-accreting and beach-eroding waves. However, the influence of climate change (not just rising sea level) on wave conditions, through changes in wave height, wave direction, storm frequency, and storm intensity, will likely be far more significant than the slight changes from bathymetric changes. In addition, changing precipitation patterns will modify the amount and timing of sediment delivery to the beach.

[104] In shallow water, wave energy is proportional to the square of the water depth. As water depths increase with sea level rise, wave energy at the same location will likewise increase.

[105] Many parts of the developed coast are already experiencing drops in sand supplies due to upstream impoundments of water and sediment, more impervious surfaces, and sand mining.

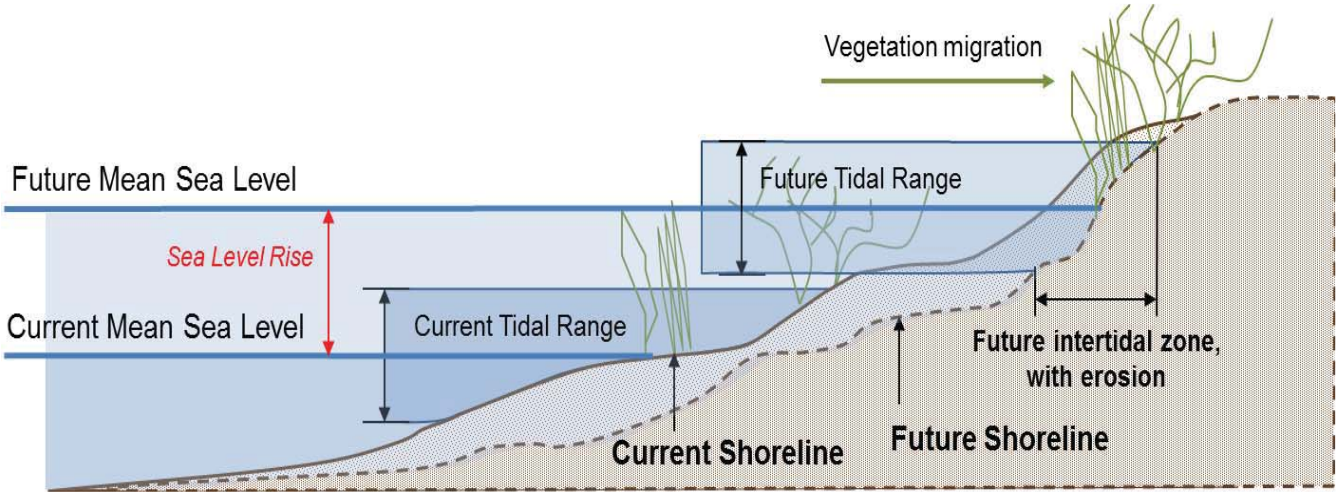

Figure B-5. Changes to the intertidal zone with sea level rise and erosion, without wave impacts. (*Source: L. Ewing, 2013*).

Bluff Erosion

A second type of erosion occurs on coastal bluffs.[106] There is no fully-accepted methodology for estimating future bluff erosion with sea level rise. Guidance for coastal analysts in Hawaii is to assume erosion will increase as a proportion of historical erosion (Hwang 2005). One approach used in the past by the Commission has been to apply one of the higher rates of historical erosion to represent average future trends. A more process-based methodology, used in the Pacific Institute study of erosion due to rising sea level, is to correlate future erosion rates of bluffs with a higher still water level that will allow waves to attack the bluff more frequently (Heberger *et al.* 2009; Revell *et al.* 2011). This approach assumes that all bluff erosion is due to wave impacts and that erosion rates will change over time as the beach or bluff experiences more frequent or more intense wave attack. Such an approach should be considered for examining bluff erosion with rising sea level. Other approaches that recognize the influence of water levels in beach, bluff, or dune erosion can also be used.

Bluff retreat occurs via many different mechanisms. Landslides, slumps, block failures, gullies, and rilling are examples of bluff retreat. At the most basic level, bluff retreat or collapse occurs when the forces leading to collapse of the bluff face are stronger than the forces holding the bluff in place. Forces causing bluff retreat can include earthquakes, wind, burrowing animals, gravity, rain, surface runoff, groundwater, and sheet flow. Coastal bluffs have the added factor of wave attack. Resistance to collapse is mainly a characteristic of the bluff material. For example, granitic bluffs like those along the Big Sur coast retreat at a much slower rate than the soft sandstone and marine terrace bluffs of Pacifica.

[106] Bluffs can be built or expanded during interglacial cycles or following seismic uplift. Many of the marine terraces that are visible along the California coast are remnants of past beach areas that have been uplifted to become bluffs and cliffs. However, natural bluff rebuilding is a millennial or multi-millennial process, and it will not occur during the time periods over which most development projects are evaluated.

Coastal bluff erosion can occur throughout the year, but it often occurs during or after storm periods, when the dry beach will be narrow or non-existent. When coastal bluffs are fronted by wide sand beaches, most waves break on the beach face and the beaches protect the bluffs from direct wave attack. When the beach is narrow, there is less buffering of the wave energy and waves can break directly against the bluffs. A general depiction of bluff retreat with rising sea level is provided in Figure B-6.

Bluff retreat is often episodic – the bluff may be stable for a number of years and then retreat by tens of feet in a few hours or a few days. If the changes to a bluff are examined through endpoint analysis (*i.e.*, looking first at the initial position of the bluff and then at the position of the bluff sometime in the future), researchers can determine the amount of retreat that has occurred during the time from the initial to final positions. This gives information on an average retreat rate that has occurred, but provides no insight about the conditions leading to the retreat, the size of retreat, frequency of retreat events, or the progression of retreat and no retreat. The average retreat rates can give some indication of likely future changes, but they provide little information about when the next retreat episode might occur or how large it might be.

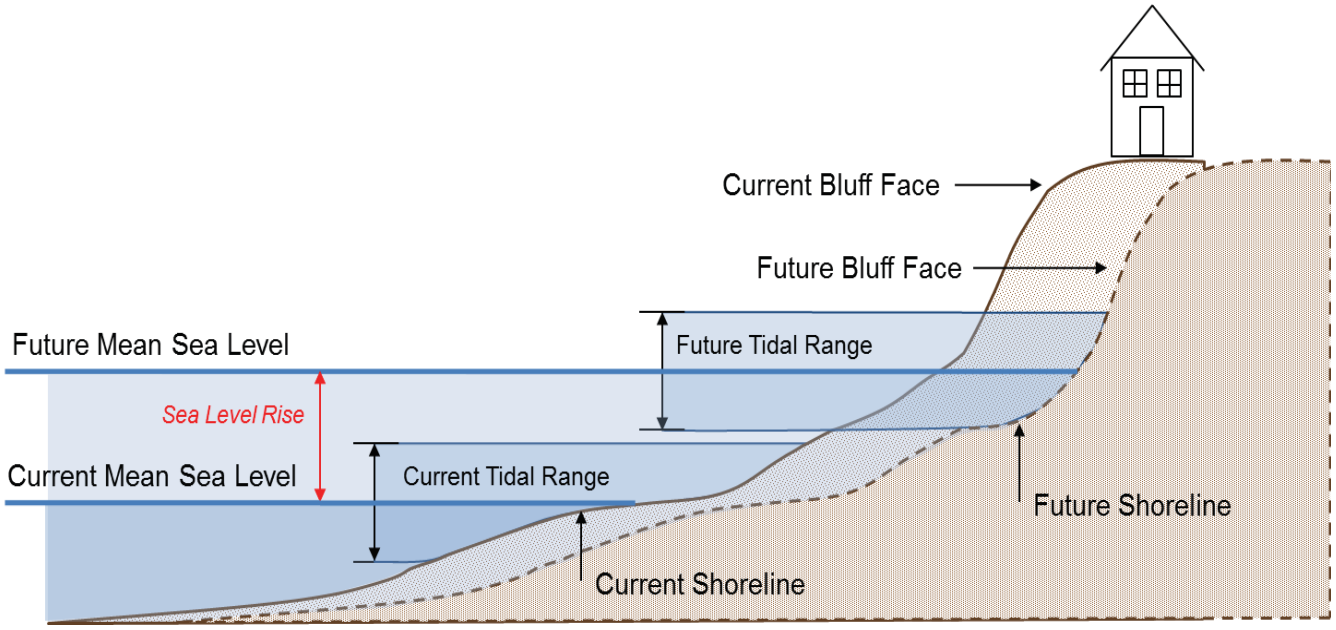

Figure B-6. Bluff erosion with changes in sea level. (*Source: L. Ewing, 2013*).

Dune Erosion

Just as there is no fully-accepted methodology for estimating changes to beach or bluff erosion with sea level rise, there is no fully-accepted methodology for dune erosion. A methodology somewhat similar to that for bluff erosion has been developed for dunes (Heberger *et al.* 2009; Revell *et al.* 2011), and such an approach should be considered for examining dune erosion with rising sea level. Other approaches that recognize the influence of water levels in beach, bluff, or dune erosion may also be used.

Dune erosion occurs when the waves break at or near the dunes, pulling sediment out of the dune. This process deposits sand onto the beach or in the nearshore area, but can result in short-term dune retreat. If sand is not returned to the dunes following these periods of short-term retreat, the sand losses will contribute to long-term dune erosion. Damage will occur to development located on dunes when the dune retreats back to the location of development, either through reversible, short-term retreat or long-term erosion.

For individual cases, determinations of future retreat risk are based on the site-specific conditions and professional analysis and judgment. However, the lack of information about the contributions of all the erosive forces to dunes and the beach-dune interactions makes it challenging to anticipate future changes to coastal dune retreat due to rising sea level and increased wave forces. As with beaches and bluffs for most situations, historical conditions provide a lower limit for future dune *retreat*, or the upper limit of dune *advance* for those sites that are now experiencing accretion or quasi-stability. Projections of future erosion should either: 1) use the high range of historical erosion; 2) develop a sea level rise influenced erosion rate, as done by Heberger *et al.* (2009) or Revell *et al.* (2011); or, 3) develop another approach that considers shoreline changes that are likely to occur under rising sea level conditions.

Table B-5. General Resources for Information on Beach, Bluff and Dune Erosion

Resource	Description	Link
Aerial Photographs	Useful for general information on shoreline trends; ortho-rectified photos can help quantify trends.	California Coastal Records Project, www.californiacoastline.org; Huntington Library; Local Libraries
LIDAR	Fairly detailed topography that can provide GIS layers for current conditions and is comparable with LIDAR data sets for temporal changes.	NOAA's Digital Coast, http://coast.noaa.gov/digitalcoast/data/coastallidar
USGS National Assessment of Shoreline Change with GIS Compilation of Vector Shorelines	Statewide inter-annual beach and bluff erosion; GIS shorelines available for sandy shorelines & cliff edge, showing historical changes for long-term (70 to 100 years) and short-term (25 to 50 years). No projections of future erosion rates available.	Sandy Shorelines – Open File Report 2006-1219, http://pubs.usgs.gov/of/2006/1219, and GIS Data in Open File 2006-1251, http://pubs.usgs.gov/of/2006/1251; Bluff Shorelines – Open File Report 2007-1133, http://pubs.usgs.gov/of/2007/1133, and GIS Data in Open File 2007-1251, http://pubs.usgs.gov/of/2007/1112

Regional Sediment Management Studies	Summaries of seasonal and long-term erosion studies	CSMW Website, http://dbw.ca.gov/csmw/default.aspx; California Beach Erosion Assessment Survey, http://dbw.ca.gov/csmw/library.aspx
US Army Corps of Engineers, Coast of California Studies	Summaries of seasonal and long-term erosion studies	Studies for many regions are available through an internet search (addresses are too numerous to list here)
Beach Profiles and Surveys	Detailed beach or bluff changes with time	NOAA's Digital Coast, http://coast.noaa.gov/digitalcoast/tools/list; US Army Corps of Engineers; Regional Beach Studies; University Studies
The Impacts of Sea Level Rise on the California Coast (Pacific Institute Report)	Expected changes to bluff position over time for sea level rise of 4.6 ft (1.4 m) from 2000 to 2100 for California coast from Oregon border through Santa Barbara County.	Pacific Institute Website, http://www.pacinst.org/reports/sea_level_rise/maps/
CoSMoS	Tool for predicting climate change impacts from storms. The *Our Coast, Our Future* effort, from Half Moon Bay to Bodega Bay, does not predict long-term erosion, but can provide general information for short-term, storm-driven beach changes. The Southern California version (from Point Conception to the US-Mexico border, including the Channel Islands and coastal embayments) does account for shoreline change and fluvial inputs.	http://walrus.wr.usgs.gov/coastal_processes/cosmos/
Coastal Resilience Ventura	A partnership to provide science and decision-support tools to aid conservation and planning projects and policymaking to address conditions brought about by climate change. The primary goals of Coastal Resilience Ventura are assessing the vulnerabilities of human and natural resources, and identifying solutions that help nature help people. The mapping tool includes flooding and inundation risk, wave impacts, and erosion risk.	http://coastalresilience.org/geographies/ventura-county

Outcome from Step 4: *Provide projections of future long-term beach, bluff or dune erosion that takes into account sea level rise. For locations without any influence from storm surge, or wave energy, the identification of the extent of beach, bluff or dune erosion may be sufficient for project analysis and planning efforts. This projected new erosion area may also be useful for anticipating the appropriate setback distance for otherwise stable land forms (If slope stability is a concern, refer to Commission guidance on setbacks (*http://www.coastal.ca.gov/W-11.5-2mm3.pdf*)). For most open coast situations, this information will be used to inform further project analysis and planning that examines erosion, surge and storm conditions.*

Step 5 – Determine wave, storm wave, wave runup, and flooding conditions

The main concerns with waves, storm waves, and runup are flooding and damage from wave impacts. Flooding is the temporary wetting of an area by waves, wave runup, surge, atmospheric forcing (such as water elevation during El Niño events) and, at river mouths, the combination of waves and river flows. Wave impacts occur when high-energy waves, often associated with storms, reach backshore areas or development. Coastal flooding and wave impacts are worst when they coincide with high water level events (high tide plus high inundation). As sea level rises, inundation will move inland, and so will flooding and wave impacts. Beach erosion will aggravate these conditions and add to the inland extent of impacts.

Flooding

In most situations, factors that result in high water conditions, such as tides, surge, El Niño events, and PDOs, should be used to determine flood levels and flood areas, as shown below. If the area is exposed to storm waves, these forces should be examined as well.

Future Flooding Level = Higher High Tide + Sea Level Rise + Surge + Forcing + Wave Runup

Flooding Areas = Flooding + Seasonal Eroded Beach + Long-Term Beach Erosion

Waves

Waves, like tides, cause constant changes to the water levels that are observed at the coast. The rhythmic lapping of waves on the beach during summer can be one of the joys of a beach visit. At other times of the year, waves can increase in size and energy and damage or destroy buildings, and cause erosion of bluffs and cliffs. Routine ocean waves are generated by wind blowing across the surface of the water and can travel far from their source, combining with waves generated from other locations to produce the rather erratic and choppy water levels that are seen in most of the ocean. As waves move into shallow water and approach land, they are strongly modified by the offshore bathymetry. They take on a more uniform appearance, aligning somewhat parallel to the shoreline through processes of refraction and diffraction. During most of the year, moderate short-period waves break once they are in water depths of approximately 1.3 times the wave height.

Wave impacts depend greatly upon storm activity – both the intensity and the duration of the storm. Normally projects have used design wave conditions comparable to the 100-year event. For critical infrastructure or development with a long life expectancy, it may be advisable to use a greater design standard, such as a 200-year or 500-year event. It may be suitable for some proposed projects to adjust design waves or the frequency of high energy waves to analyze the consequences of worsening wave impacts.

Waves also vary greatly with bathymetry; offshore reefs and sand bars can cause waves to break far from the coast and greatly reduce the energy of the waves that come onshore. Therefore, changes in offshore water depths can alter the nature of nearshore wave propagation and resultant onshore waves. For areas with complex offshore bathymetry, wave impact changes due to rising sea level may need to be examined in the context of both offshore and nearshore conditions.

Wave impacts to the coast, to coastal bluff erosion and inland development, should be analyzed under the conditions most likely to cause harm. Those conditions normally occur in winter when most of the sand has moved offshore leaving only a reduced dry sand beach to dissipate wave energy (this seasonal change in beach width is often referred to as short-term or seasonal erosion). On beaches that will experience long-term erosion, trends expected to occur over the entire expected life of the development should also be considered. Just as the beach conditions to analyze should be those least likely to protect from damage over the life of the development, the water level conditions considered should also be those most likely to contribute to damage over the life of the development. Waves that cause significant damage during high tide will be less damaging during low tide; all other things being equal, waves will cause more inland flooding and impact damage when water levels are higher. Since water levels will increase over the life of the development due to rising sea level, the development should be examined for the amount of sea level rise (or a scenario of sea level rise conditions) that is likely to occur throughout the expected life of the development. Then, the wave impact analysis should examine the consequences of a 100-year design storm event using the combined water levels that are likely to occur with high water conditions and sea level rise, as well as a long-term and seasonally eroded beach.

Eroded Beach Conditions = Seasonal Erosion + Long-Term Erosion*

High Water Conditions = High Tide + Relative Sea Level Rise* + Atmospheric Forcing

Wave Conditions = 100-year Design Storm + High Water + Eroded Beach

* The time period for both long-term erosion and relative sea level rise will be at least as long as the expected life of the development.

The remaining discussion provides general information about waves, the California wave climate, and coastal flooding. It is provided to acquaint readers to the main issues associated with waves and coastal flooding. Readers with a strong background in waves or coastal processes may want to skim or skip the rest of this section.

Storm Waves

During storm conditions, winds can transfer large amounts of energy into waves, increasing wave height, length, and period. Energy transfer to waves depends upon three conditions: the wind energy that is available to be transferred to the water (intensity); the length of time over which the wind blows (duration); and the area over which the wind blows (the fetch). As any of these conditions increases, the energy in the waves will increase, as will the energy that these waves bring to the coastline. Coastal scientists separate waves that are generated far from the coast (swell) from waves that are locally generated (seas). Storms in the mid-Pacific can cause storm-like wave conditions along the coast, even when there are no storms in the area. Likewise, a local storm can cause storm waves along one part of the coast while waves in other sections of the coast may be fairly mild.

Some of the worst storm wave conditions occur when there are intense storms along a large portion of the coast and when this large, distantly generated swell combines with local seas. The 1982/83 El Niño has been cited often as one of the more damaging storm seasons in recent times. In late January 1983, waves from a distant storm combined with locally generated waves and the highest tides of the year. This one storm caused substantial damage along much of the California Coast. The coast was not able to recover before a series of storms in February and March caused additional damage. The full 1982/83 El Niño storm season resulted in damage to approximately 3,000 homes and 900 businesses and destruction of 33 buildings. Damages exceeded $100 million to structures and $35 million to public recreational infrastructure (in 1982 dollars; Flick 1998).

Wave Runup

Wave runup, as depicted in Figure B-7, is the distance or extent to which water from a breaking wave will spread up the shoreline. Much of the wave energy will dissipate during breaking, but wave runup can also be damaging. The runup water moves quickly and can scour or erode the shoreline areas (including the beach), damage structures, and flood inland areas.

Damage from waves and wave runup may increase in the future, due both to rising sea level and to changes in storm intensity and frequency. Waves will break farther landward when water levels are higher. Therefore, increased water levels due to tides, surge, ENSO or PDO variability, or sea level rise will enable more wave energy to reach the beach, back shore, or inland development. The higher water levels do not change the waves. Rather, higher water levels change the point of impact, the extent of runup, and the frequency of wave impact. In locations where high waves now hit the coast, that frequency will increase; in locations where high waves rarely hit the coast, exposure to wave impacts will increase. Increased exposure to wave impacts or wave runup can cause a greater risk of flooding, erosion, bluff failure, and/or damage to

development. But, since the focusing of wave energy is strongly influenced by offshore bathymetry, locations of wave exposure may also change with rising sea level and modifications in wave propagation might result from future differences in water depths.

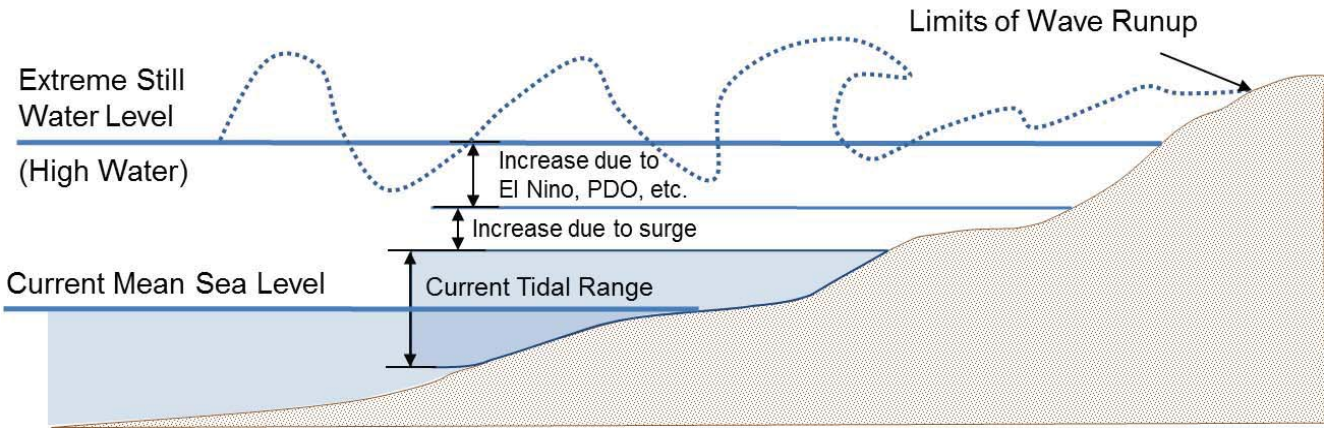

Figure B-7. Wave runup combined with extreme still water (High Water). (*Source: L. Ewing, 2013*).

Summary

Coastal flooding is a significant problem now and it will increase with rising sea level. At present, about 210,000 people in California are living in areas at risk from a 100-year flood event (Heberger *et al.* 2009). A rise in sea level of 55 in (1.4 m) with no change in development patterns or growth along the coast could put 418,000 to 480,000 people at risk from a 100-year flood (Cooley *et al.* 2012). An additional fraction of the California population that relies on critical infrastructure located in potentially hazardous areas is also vulnerable and increases in storm intensity or in the density of development in flood-prone areas will increase the number of people at risk from flooding.

The frequency and intensity of high wave events depends upon the storm conditions that generate the waves. There is less consistency in the output of climate models related to projections of future storm conditions than there has been for temperature projections. A recent report on coastal flooding from years 2000 to 2100 for the California coast has found that "storm activity is not projected to intensify or appreciably change the characteristics of winter nearshore wave activity of the twenty-first century" (Bromirski *et al.* 2012, p. 33). This continuation of current storm conditions is not, however, an indication that storms will not be a problem in the future. Storm damage is expected to continue, and, if sea level rise by the end of the twenty-first century reaches the high projections of about 55 in (1.4 m), "coastal managers can anticipate that coastal flooding events of much greater magnitude than those during the 1982-83 El Niño will occur annually." (Bromirski *et al.* 2012, p. 36)

For most situations, the 100-year storm event should be used as the design storm. This is equivalent to a storm with a 1% annual probability of occurrence. However, most development does outlast one year and this probability of occurrence grows over time such that there is a 22% probability of occurrence during a 25-year period and over 53% probability that this storm will occur at least once during a 75-year period. Even so, the 100-year storm event, like the 100-year flood event, is often used as a design standard for development. However, for structures with a

very long projected life or for which storm protection is very critical, a larger, 200-year or 500-year event might be appropriate.

Table B-6 lists many of the resources that are available for finding regional or state-wide information on waves and flooding. Local communities may have records of major erosion episodes or flood events as well.

Table B-6. General Resources for Flooding and Wave Impacts

Resource	Description	Link
CDIP (Coastal Data Information Program)	Current and historical information on wind, waves, and water temperature, wave and swell models and forecasting. As of 2013, there are 19 active stations along the California coast.	http://cdip.ucsd.edu/
Flood Insurance Rate Maps (FIRMs)	FEMA is updating coastal flood maps. Existing FIRMs are based on 1980s topography; flooding includes seasonal beach change but not long-term erosion. Maps do not include sea level rise. Inclusion of a site shows a flood hazard; but exclusion does not necessarily indicate a lack of flood hazard.	FEMA Flood Map Service Center, https://msc.fema.gov/portal
FEMA Flood Hazard Mapping Guidance	*Subsection D.2.8* provides guidance for calculating wave runup and overtopping on barriers. There are special cases for steep slopes and where runup exceeds the barrier or bluff crest.	https://www.fema.gov/media-library/assets/documents/13948
Regional Sediment Management Studies	Some studies show elements of beach flooding and wave impacts.	http://dbw.ca.gov/csmw/default.aspx
Cal-Adapt – Exploring California's Climate	Shows coastal areas that may be threatened by flooding from a 4.6 ft (1.4 m) rise in sea level and a 100-year flood event. Maps were developed using the Pacific Institute SLR Maps and do not now include any influence of beach or dune erosion, or existing protective structures.	http://cal-adapt.org/sealevel/
US Army Corps of Engineers, Coastal Engineering Manual	Detailed information on all aspects of deep-water wave transformation, shoaling, runup, and overtopping.	http://chl.erdc.usace.army.mil/cem
European Overtopping Manual	Descriptions of available methods for assessing overtopping and its consequences. Provides techniques to predict wave overtopping at seawalls, flood embankments, breakwaters and other shoreline structures facing waves. Supported by web-based programs for the calculation of overtopping discharge and design details.	http://www.overtopping-manual.com/

CoSMoS	A tool to help understand, visualize, and anticipate vulnerabilities from sea level rise and storms. It does not predict long-term erosion, but can provide general information for short-term, storm-drive beach changes. Currently available for the central coast, but expanding to southern California in 2015/2016.	http://walrus.wr.usgs.gov/coastal_processes/cosmos/
Coastal Resilience Ventura	A partnership to provide science and decision-support tools to aid conservation and planning projects and policymaking to address conditions brought about by climate change. The primary goals of Coastal Resilience Ventura are assessing the vulnerabilities of human and natural resources, and identifying solutions that help nature help people. The mapping tool includes flooding and inundation risk, wave impacts, and erosion risk.	http://coastalresilience.org/geographies/ventura-county

Outcome from Step 5: *Provide projections of future flooding and wave impacts resulting from waves, storm waves and runup, taking into account sea level rise.*

Step 6 – Examine potential flooding from extreme events

Extreme events[107], by their very nature, are those beyond the normal events that are considered in most shoreline studies. Examples of extreme events that might occur along the California coast include:

- An individual storm with an intensity at or above the 100-year event
- A series of large, long-duration storms during high tides
- A local storm that coincides with the arrival of distant swell and high tides
- Rapid subsidence, as might happen along the Northern California coast during a Cascadia Subduction Zone earthquake
- Global sea level rise greater than that projected to occur by 2100, when combined with a large storm during normal tides

Planning and project analysis need to consider and anticipate the consequences of these outlier events. In many situations, this assessment might be a qualitative consideration of consequences that could happen if an extreme event does occur. Analysis of the consequences of extreme events presents opportunities to address some of those potential impacts through design and adaptation.

[107] In its report on *Managing the Risks of Extreme Events and Disasters to Advance Climate Change Adaptation*, the IPCC defines extreme events as "a facet of climate variability under stable or changing climate conditions. They are defined as the occurrence of a value or weather or climate variable above (or below) a threshold value near the upper (or lower) ends ("tails") of the range of observed values of the variable" (IPCC 2012).

In California, there may be some worsening of extreme precipitation and inland flooding from projected changes to atmospheric rivers, narrow bands of concentrated moisture in the atmosphere. In general, however, future extremes are likely to be comparable to the extremes of today, but with the added influence of sea level rise. Extreme storm waves or floods can be addressed with the guidance provided earlier, except that the extreme storm conditions would be used. For tsunamis it is recommended that, for most situations, the appropriate projection of sea level rise be added to the currently projected inundation level from tsunamis. This will provide a close approximation for future inundation from extreme tsunamis. If a detailed analysis of future tsunami impacts is needed, the analysis should be conducted by someone experienced in modeling tsunami waves.

Tsunamis

Tsunamis are large, long-period waves that can be generated by submarine landslides, subaerial landslides (slope failures from land into a water body), large submarine earthquakes, meteors, or volcanic eruptions. They are rare events, but can be extremely destructive when they occur. The extent of tsunami damage will increase as rising water levels allow tsunami waves to extend farther inland. Thus the tsunami inundation zone will expand inland with rising sea level. There has been no research that suggests that climate change will increase the intensity or frequency of seismically-generated tsunamis. However, the number and size of coastal subaerial landslides may increase because of increased coastal erosion due to sea level rise, which in turn may increase the potential for tsunamigenic landslides along the California coast (Highland 2004; Walder *et al.* 2003).

The detailed changes to the inundation zone with rising sea level need to be determined by modeling; however, modeling of long-waves, such as tsunamis, is a specialized area of coastal engineering, and will not be covered in this general Guidance. For most situations, it will be sufficient to get information on possible inundation from the most recent tsunami inundation maps (currently on the Department of Conservation website, http://www.conservation.ca.gov/cgs/geologic_hazards/Tsunami/Inundation_Maps/Pages/Statewide_Maps.aspx). The California Geological Survey and California Governor's Office of Emergency Services are creating new tsunami inundation maps based on probabilistic tsunami hazard analysis (CPTHAWG 2015). As a rough approximation, the change to the tsunami inundation level can be estimated as equal to the change in water elevation due to sea level; a 1-ft rise in sea level could be assumed to result in a 1-ft rise in the inundation elevation. However, in many places, particularly shallow bays, harbors, and estuaries, the change in tsunami inundation zone is likely to scale non-linearly with sea level rise and require careful modeling. California Geological Survey is also working to evaluate the impact of sea level rise with numerical tsunami modeling to verify that an additive approach (tsunami height + SLR) is the appropriate method for integrating SLR and tsunami inundation together. In areas with high tsunami hazards, or where critical resources are at risk, a site-specific analysis of sea level rise impacts on tsunami hazards is crucial, and someone experienced in modeling tsunami waves should be consulted.

Summary

Many different factors affect the actual water levels that occur along the coast and resulting hazards. In California, waves and tides have the largest routine effect on water levels. Tsunamis may have a very large, but infrequent effect on water levels. Sea level rise will affect water levels all along the coast. Until the mid-century, tides and storms are expected to have the biggest effects on local water levels, with sea level rise being a growing concern. After Year 2050, sea level rise is expected to become increasingly influential on water levels and in contributing to damages to inland areas from flooding, erosion and wave impacts. Table B-7 provides a general characterization of all the factors that can affect local water levels, with general estimates of their range and frequency of occurrence.

Outcome from Step 6: *Projections of potential flooding from extreme events including rapid subsidence, extreme precipitation, and tsunamis.*

Table B-7. Factors that Influence Local Water Level Conditions

Factors Affecting Water Level	Typical Range for CA Coast (ft)	Typical Range for CA Coast (m)	Period of Influence	Frequency
Tides	3 – 10	1 – 3	Hours	Twice daily
Low pressure	1.5	0.5	Days	Many times a year
Storm Surge	2 – 3	0.6 – 1.0	Days	Several times a year
Storm Waves	3 – 15	1 – 5	Hours	Several times a year
El Niño events (within the ENSO cycle)	<1.5	< 0.5	Months - Years	2 – 7 years
Tsunami waves	20 – 50 (max) 3 – 10 (typical)	6 – 15 (max) 1 – 3 (typical)	Minutes, Hours, Days	Infrequent but unpredictable
Historical Sea Level, over 100 years	0.7	0.2	Ongoing	Persistent
NRC State-wide Sea Level Projections 2000 – 2050	0.7 – 1.4	0.2 – 0.4	Ongoing	Persistent
NRC State-wide Sea Level Projections 2000 – 2100	0.3 – 4.69 ft (North of Cape Mendocino) 1.38 – 5.48 ft (South of Cape Mendocino)	0.1 – 1.43 m (North of Cape Mendocino) 0.42 – 1.67 m (South of Cape Mendocino	Ongoing	Persistent

Note that all values are approximations. The conversions between feet and meters have been rounded to maintain the general ranges and they are not exact conversions. *Sources*: Flick 1998; NRC 2012; Personal communications from Dr. Robert Guza (Scripps Institution of Oceanography), Dr. William O'Reilly (Scripps Institution of Oceanography and University of California, Berkeley), and Rick Wilson, California Geological Survey; and professional judgment of staff.

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Appendix C

Resources for Addressing Sea Level Rise

This section contains lists of sea level rise viewers, guidebooks, guidance documents, and state agency-produced resources, and data clearing houses related to sea level rise. These resources will be particularly relevant for informing Steps 1-6 of the LCP planning process (Chapter 5). Tables include:

- Table C-1 – Sea Level Rise Mapping Tools.
  This may be particularly relevant for Steps 1-3.

- Table C-2 – Sea Level Rise Data and Resource Clearinghouses.
  This may be particularly relevant for Steps 1-4.

- Table C-3 – Adaptation Planning Guidebooks.
  This may be particularly relevant for Steps 1-3.

- Table C-4 – Resources for Assessing Adaptation Measures.
  This may be particularly relevant for Step 4.

- Table C-5 – Examples of Sea Level Rise Vulnerability Assessments in California.
  This may be particularly relevant for Steps 1-3.

- Table C-6 – California Climate Adaptation Plans that Address Sea Level Rise.
  This may be particularly relevant for Steps 1-4.

- Table C-7 – California State Agency Resources

Table C-1. Sea Level Rise Mapping Tools

Tool	Description	Link
Statewide		
NOAA Digital Coast Sea Level Rise and Coastal Flooding Impacts Viewer	Displays potential future sea levels with a slider bar. Communicates spatial uncertainty of mapped sea level rise, overlays social and economic data onto sea level rise maps, and models potential marsh migration due to sea level rise. Maps do not include any influence of beach or dune erosion.	http://coast.noaa.gov/digitalcoast/tools/slr/
Cal-Adapt – Exploring California's Climate	Shows coastal areas that may be threatened by flooding from a 4.6 ft (1.4 m) rise in sea level and a 100-year flood event. Maps were developed using the Pacific Institute SLR Maps (see below) and do not now include any influence of beach or dune erosion or existing protective structures.	http://cal-adapt.org/sealevel/
Climate Central Surging Seas	Overlays sea level rise data with socio-economic information and ability to analyze property values, population, socio-economic status, ethnicity, and income or areas at risk. Can compare exposure across the whole state or selected county.	http://sealevel.climatecentral.org/ssrf/california
Pacific Institute Sea Level Rise Maps (Heberger *et al*. 2009)	Downloadable PDF maps showing the coastal flood and erosion hazard zones from the 2009 study. Data are overlaid on aerial photographs and show major roads. Also available are an interactive online map and downloadable maps showing sea level rise and population and property at risk, miles of vulnerable roads and railroads, vulnerable power plants and wastewater treatment plants, and wetland migration potential.	http://www.pacinst.org/reports/sea_level_rise/maps/ For the 2009 report *The Impacts of Sea-Level Rise on the California Coast*, see: http://pacinst.org/publication/the-impacts-of-sea-level-rise-on-the-california-coast/

Sea Level Affecting Marshes Model (SLAMM)	Simulates the dominant processes involved in wetland conversions and shoreline modifications during long-term sea level rise. Map distributions of wetlands are predicted under conditions of accelerated sea level rise, and results are summarized in tabular and graphical form.	http://www.warrenpinnacle.com/prof/SLAMM
Coastal Storm Modeling System (CoSMoS)	A numerical modeling system to predict coastal flooding due to both sea level rise and storms driven by climate change. Used in the *Our Coast Our Future* project (along the Central Coast) and for the entire Southern California Bight (expected to be available in 2015).	*OCOF*: http://data.prbo.org/apps/ocof/ Southern CA: http://walrus.wr.usgs.gov/coastal_processes/cosmos/socal2.0/index.html
North Coast		
Humboldt Bay Sea Level Rise Adaptation Project	This project is a multi-phased, regional collaboration. Phase I produced the *Humboldt Bay Shoreline Inventory, Mapping, and Sea Level Rise Vulnerability Assessment* which describes current shoreline conditions and vulnerabilities under the current tidal regime. Phase II included hydrodynamic modeling to develop vulnerability maps of areas surrounding Humboldt Bay vulnerable to inundation from existing and future sea levels. Phase II produced the *Humboldt Bay Sea Level Rise Modeling Inundation Mapping Report* and the *Humboldt Bay Sea Level Rise Conceptual Groundwater Model*.	All reports are available at: http://humboldtbay.org/humboldt-bay-sea-level-rise-adaptation-planning-project

North Central Coast		
Our Coast Our Future (map available for Bodega Head to Half Moon Bay)	Provides online maps and tools to help understand, visualize, and anticipate vulnerabilities to sea level rise and storms, including seamless Digital Elevation Model (DEM) at 6.6 ft (2 m) horizontal resolution; 9.8 in (25 cm) increment sea level rise projections between 0-6.6 ft (0-2 m) with a 16.4 ft (5 m) extreme; storm scenarios using the Coastal Storm Modeling System (CoSMoS); and interactive maps overlaying infrastructure and ecosystem vulnerabilities.	http://data.prbo.org/apps/ocof/
South Coast		
Coastal Resilience Ventura	A partnership to provide science and decision-support tools to aid conservation and planning projects and policymaking to address conditions brought about by climate change. The primary goals of Coastal Resilience Ventura are assessing the vulnerabilities of human and natural resources, and identifying solutions that help nature help people.	http://maps.coastalresilience.org/california/ http://coastalresilience.org/geographies/ventura-county
Southern California Coastal Impacts Project, including the Coastal Storm Modeling System (CoSMoS)	A numerical modeling system to predict coastal flooding due to both sea level rise and storms driven by climate change; conditions will be specifically selected for and downscaled to the southern California region (from Point Conception to the US-Mexico border, including the Channel Islands and coastal embayments). This version will take into account shoreline change and fluvial inputs; additionally, even more robust modeling of coastal erosion and shoreline change will be provided for the Los Angeles region.	http://walrus.wr.usgs.gov/coastal_processes/cosmos/socal2.0/index.html

Table C-2. Sea Level Rise Data and Resource Clearinghouses

Resource	Description	Link
California Climate Commons	Offers a point of access to climate change data and related resources, information about the science that produced it, and the opportunity to communicate with others about applying climate change science to conservation in California.	http://climate.calcommons.org/
Climate Adaptation Knowledge Exchange (CAKE)	Provides an online library of climate adaptation case studies and resources, plus ways to connect with an online climate adaptation community/ network.	http://www.cakex.org/
Ecosystem Based Management Tools Network Database	Provides a searchable database of tools available for climate adaptation, conservation planning, sea level rise impact assessment, *etc.*	http://www.ebmtools.org/about_ebm_tools.html
Climate.Data.gov	Recently launched federal government data portal that includes a number of data sets on climate change, including sea level rise impacts.	http://www.data.gov/climate/
NOAA Digital Coast	This NOAA-sponsored website is focused on helping communities address coastal issues. The Digital Coast provides coastal data, tools, training, and information from reputable sources.	http://coast.noaa.gov/digitalcoast/

Table C-3. Adaptation Planning Guidebooks

Title	Description	Link
Scanning the Conservation Horizon (National Wildlife Federation 2011)	Designed to assist conservation and resource professionals to better plan, execute, and interpret climate change vulnerability assessments.	http://www.habitat.noaa.gov/pdf/scanning_the_conservation_horizon.pdf
Adapting to Sea Level Rise: A Guide for California's Coastal Communities (Russell and Griggs 2012)	Intended to assist California's coastal managers and community planners in developing adaptation plans for sea level rise that are suited to their local conditions and communities.	http://seymourcenter.ucsc.edu/OOB/Adapting%20to%20Sea%20Level%20Rise.pdf
California Adaptation Planning Guide (APG) (Cal EMA/CNRA 2012)	Provides guidance to support regional and local communities in proactively addressing the unavoidable consequences of climate change. Includes a step-by-step process for local and regional climate vulnerability assessment and adaptation strategy development.	http://resources.ca.gov/climate/safeguarding/adaptation_policy_guide/
Preparing for Climate Change: A Guidebook for Regional and State Governments (Snover *et al.* 2007)	Assists decision makers in a local, regional, or state government prepare for climate change by recommending a detailed, easy-to-understand process for climate change preparedness based on familiar resources and tools.	http://cses.washington.edu/db/pdf/snoveretalgb574.pdf
Adapting to Climate Change: a Planning Guide for State Coastal Managers (NOAA 2010)	Guide offers a framework for state coastal managers to follow as they develop and implement climate change adaptation plans in their own states.	http://coastalmanagement.noaa.gov/climate/docs/adaptationguide.pdf

Using Scenarios to Explore Climate Change: A Handbook for Practitioners (NPS 2013)	Describes the five-step process for developing multivariate climate change scenarios taught by the Global Business Network (GBN). Detailed instructions are provided on how to accomplish each step. Appendices include a hypothetical scenario exercise that demonstrates how to implement the process and some early examples of how national parks are using climate change scenarios to inform planning and decision making.	http://www.nps.gov/subjects/climatechange/upload/CCScenariosHandbookJuly2013.pdf
Scenario Planning for Climate Change Adaptation: A Guidance for Resource Managers (Moore *et al.* 2013)	Step-by-step guide to using scenarios to plan for climate change adaptation for natural resource managers, planners, scientists, and other stakeholders working at a local or regional scale to develop resource management approaches that take future climate change impacts and other important uncertainties into account.	http://scc.ca.gov/files/2013/07/Scen-planning_17july2013_FINAL-3.pdf

Table C-4. Resources for Assessing Adaptation Measures

Resource	Description	Link
General		
Georgetown Climate Center's Climate Adaptation Toolkit – Sea Level Rise and Coastal Land Use	Explores 18 different land-use tools that can be used to preemptively respond to the threats posed by sea level rise to both public and private coastal development and infrastructure, and strives to assist governments in determining which tools to employ to meet their unique socio-economic and political contexts.	http://www.georgetownclimate.org/resources/adaptation-tool-kit-sea-level-rise-and-coastal-land-use
What Will Adaptation Cost? (ERGI 2013)	"This report provides a framework that community leaders and planners can use to make more economically informed decisions about adapting to sea level rise and storm flooding. The four-step framework can be used to perform a holistic assessment of costs and benefits of different adaptation approaches across a community, or to focus in on select infrastructure. The report also discusses the expertise needed at each step in the process."	http://coast.noaa.gov/digitalcoast/publications/adaptation
Center for Ocean Solutions: Adaptation in Action: Examples from the Field	Provides case studies of various adaptation strategies including overlay zones, non-conformities, setbacks, buffers, development conditions, shoreline protection devices, managed retreat, capital improvement programs, acquisition programs, conservation easements, rolling easements, tax incentives, transfer development rights, and real estate disclosures.	http://www.centerforoceansolutions.org/sites/default/files/Application%20of%20Land%20Use%20Practices%20and%20Tools%20to%20Prepare.pdf

Combatting Sea Level Rise in Southern California: How Local Government Can Seize Adaptation Opportunities While Minimizing Legal Risk (Herzog and Hecht 2013)	Identifies how local governments can harness legal doctrines to support aggressive, innovative strategies to achieve successful sea level rise adaptation outcomes for Southern California while minimizing legal risk. Broadly outlines likely sea level rise impacts in Southern California, and evaluates the risks and opportunities of potential protection, accommodation, and retreat adaptation strategies that local governments could deploy.	http://www.law.ucla.edu/~/media/Files/UCLA/Law/Pages/Publications/CEN_EMM_PUB%20Combatting%20Sea-Level%20Rise.ashx
Strategies for Erosion-Related Impacts		
Evaluation of Erosion Mitigation Alternatives for Southern Monterey Bay	Provides a technical evaluation of various erosion mitigation measures, conducts a cost benefit analysis of some of the more promising measures, and includes recommendations for addressing coastal erosion in Southern Monterey Bay. The report is intended to be relevant for other areas of California as well.	http://montereybay.noaa.gov/new/2012/erosion.pdf
Rolling Easements		
Rolling Easements- A Primer (Titus 2011)	Examines more than a dozen different legal approaches to rolling easements. It differentiates opportunities for legislatures, regulators, land trusts, developers, and individual landowners. Considers different shoreline environments (*e.g.*, wetlands, barrier islands) and different objectives (*e.g.*, public access, wetland migration)	http://papers.risingsea.net/rolling-easements.html
No Day at the Beach: Sea Level Rise, Ecosystem Loss, and Public Access Along the California Coast (Caldwell and Segall 2007)	Provides a description of sea level rise impacts to ecosystems and public access, strategies to address these impacts, and case study examples of rolling easement strategies for the California coast.	http://scholarship.law.berkeley.edu/cgi/viewcontent.cgi?article=1833&context=elq

Natural Resources		
PRBO Climate Smart Conservation	Lists science-based, climate-smart conservation planning and management tools and methods, including restoration projects designed for climate change and extremes.	http://www.pointblue.org/priorities/climate-smart-conservation/
US Forest Service System for Assessing Vulnerability of Species- Climate Change Tool	Quantifies the relative impact of expected climate change effects for terrestrial vertebrate species.	http://www.fs.fed.us/rm/grassland-shrubland-desert/products/species-vulnerability/savs-climate-change-tool/
The Nature Conservancy: Reducing Climate Risk with Natural Infrastructure report	Presents a series of nine case studies in which natural, "green" infrastructure was successfully used to mitigate climate impacts. The economic costs and benefits of the green infrastructure are compared with traditional "gray" approaches.	http://www.nature.org/ourinitiatives/regions/northamerica/unitedstates/california/ca-green-vs-gray-report-2.pdf
CDFW Essential Habitat Connectivity Project	"The California Department of Fish and Wildlife and the California Department of Transportation (Caltrans) commissioned a team of consultants to produce a statewide assessment of essential habitat connectivity by February of 2010, using the best available science, datasets, spatial analyses, and modeling techniques. The goal was to identify large remaining blocks of intact habitat or natural landscape and model linkages between them that need to be maintained, particularly as corridors for wildlife."	https://www.wildlife.ca.gov/Conservation/Planning/Connectivity
CDFW Areas of Conservation Emphasis tool	Provides a mapping tool and reports on the best available statewide, spatial information on California's biological richness, including species diversity, rarity, and sensitive habitats, as well as recreational needs and opportunities throughout the state, including fishing, hunting and wildlife-viewing.	http://www.dfg.ca.gov/biogeodata/ace/

Table C-5. Examples of Sea Level Rise Vulnerability Assessments in California

Title	Description	Link
Santa Barbara Sea Level Rise Vulnerability Study (Russell and Griggs 2012)	Assesses the vulnerability of the City of Santa Barbara to future sea level rise and related coastal hazards (by Years 2050 and 2100) based upon past events, shoreline topography, and exposure to sea level rise and wave attack. It also evaluates the likely impacts of coastal hazards to specific areas of the City, analyzes their risks and the City's ability to respond, and recommends potential adaptation responses.	http://www.energy.ca.gov/2012publications/CEC-500-2012-039/CEC-500-2012-039.pdf
City of Santa Cruz Climate Change Vulnerability Assessment (Griggs and Haddad 2011)	Delineates and evaluates the likely impacts of future climate change on the city of Santa Cruz, analyzes the risks that these hazards pose for the city, and then recommends potential adaptation responses to reduce the risk and exposure from these hazards in the future.	http://seymourcenter.ucsc.edu/OOB/SCClimateChangeVulnerabilityAssessment.pdf
Developing Climate Adaptation Strategies for San Luis Obispo County: Preliminary Vulnerability Assessment for Social Systems (Moser 2012)	Describes the likely impacts of climate change on the resources and social systems of San Luis Obispo County, and assesses key areas of vulnerability. Sea level rise is identified as a major source of risk to fishing, coastal tourism, coastal development, and infrastructure.	http://www.energy.ca.gov/2012publications/CEC-500-2012-054/CEC-500-2012-054.pdf

Monterey Bay Sea Level Rise Vulnerability Study (Monterey Bay National Marine Sanctuary and PWA ESA; In progress)	Will assess potential future impacts from sea level rise for the Monterey Bay region. The project will estimate the extent of future coastal erosion in Monterey Bay due to accelerated sea level rise and evaluate areas subjected to coastal flooding by inundation from wave action and/or storm surges. The project will update and refine existing Monterey Bay coastal hazard zones maps (erosion and flooding).	Project scope and grant details: http://scc.ca.gov/webmaster/ftp/pdf/sccbb/2012/1201/20120119Board03D_Monterey_Bay_Sea_Level_Rise.pdf
Sea Level Rise Vulnerability Study for the City of LA (Adapt LA) (USC Sea Grant 2013)	This report provides a summary of the initial research on the potential impacts of sea level rise and associated flooding from storms for coastal communities in the City of L.A. The study concentrates on the City's three coastal regions: Pacific Palisades from Malibu to Santa Monica; Venice and Playa del Rey; and San Pedro, Wilmington and the Port of Los Angeles.	http://dornsife.usc.edu/uscseagrant/la-slr/

Table C-6. California Climate Adaptation Plans that Address Sea Level Rise

Title	Description	Link
Adapting to Rising Tides (ART) Project	The ART project is a collaborative planning effort led by the San Francisco Bay Conservation and Development Commission to help SF Bay Area communities adapt to rising sea levels. The project has started with a vulnerability assessment for a portion of the Alameda County shoreline.	http://www.adaptingtorisingtides.org/ Vulnerability and risk assessment report: http://www.adaptingtorisingtides.org/vulnerability-and-risk-assessment-report/
Santa Cruz Climate Adaptation Plan	An update to the 2007 Hazard Mitigation Plan, the adaptation plan includes strategies and best available science for integrating climate change impacts into City of Santa Cruz operations.	Complete plan is available: http://www.cityofsantacruz.com/home/showdocument?id=23644
San Diego Bay Sea Level Rise Adaptation Strategy	The strategy provides measures to evaluate and manage risks from sea level rise and other climate change impacts, and includes a vulnerability assessment of community assets at risk, and broad recommendations to increase resilience of these assets.	http://sdclimatecollaborative.org/wp-content/uploads/2015/08/San-Diego-Bay-SLR-Adaptation-Strategy.pdf

Table C-7. California State Agency Resources

Agency	Document	Description and Link
California Natural Resources Agency	*Safeguarding California from Climate Change* (2014)	An update to the 2009 *California Climate Adaptation Strategy*: http://resources.ca.gov/docs/climate/Final_Safeguarding_CA_Plan_July_31_2014.pdf
	California Climate Adaptation Strategy (2009)	Summarizes climate change impacts and recommends adaptation strategies across seven sectors: Public Health, Biodiversity and Habitat, Oceans and Coastal Resources, Water, Agriculture, Forestry, and Transportation and Energy: http://resources.ca.gov/docs/climate/Statewide_Adaptation_Strategy.pdf
Office of the Governor	*Executive Order S-13-08* (2008)	This 2008 Executive Order required the CA Natural Resources Agency to develop a statewide climate adaptation strategy, and requested that the National Academy of Sciences convene an independent scientific panel to assess sea level rise in California. http://gov.ca.gov/news.php?id=11036
	Executive Order B-30-15 (2015)	This 2015 Executive Order established an interim greenhouse gas reduction target of 40 percent below 1990 levels by 2030 to expand upon the targets already included in AB32 and emphasized the need for adaptation in line with the actions identified in the *Safeguarding California* document. http://gov.ca.gov/news.php?id=18938
California Ocean Protection Council	*Resolution on Implementation of the Safeguarding California Plan for Reducing Climate Risks* (2014)	Resolves that OPC staff and the State Coastal Leadership Group on SLR will develop an action plan to implement the *Safeguarding California* plan. http://www.opc.ca.gov/webmaster/ftp/pdf/agenda_items/20140827/Item5_OPC_Aug2014_Exhibit_1_Safeguarding_Resolution_ADOPTED.pdf
	Resolution on Sea Level Rise (2011)	Recognizes that state agencies should address SLR through various actions such as the consideration of SLR risks in decision making, investment of public funds, stakeholder engagement, state SLR guidance updates, *etc*. http://www.opc.ca.gov/webmaster/ftp/pdf/docs/OPC_SeaLevelRise_Resolution_Adopted031111.pdf

Coasts & Oceans Climate Action Team (led by Ocean Protection Council)	*California State Sea-Level Rise Guidance Document* (2013)	Provides guidance for incorporating sea level rise projections into planning and decision making for projects in California. Updated to include NRC projections March 2013: http://www.opc.ca.gov/webmaster/ftp/pdf/docs/2013_SLR_Guidance_Update_FINAL1.pdf
California Coastal Conservancy	*Climate Change Policy* (2010)	Includes policies on 1) consideration of climate change in project evaluation, 2) consideration of sea level rise impacts in vulnerability assessments, 3) collaboration to support adaptation strategies, and 4) encouragement of adaptation strategies in project applications mitigation and adaptation: http://scc.ca.gov/2009/01/21/coastal-conservancy-climate-change-policy-and-project-selection-criteria/
	Project Selection Criteria (2011)	Adds sea level rise vulnerability to project selection criteria: http://scc.ca.gov/2009/01/21/coastal-conservancy-climate-change-policy-and-project-selection-criteria/
	Guidance for addressing climate change in CA Coastal Conservancy projects (2012)	Includes the following steps: 1) conduct initial vulnerability assessment, 2) conduct more comprehensive vulnerability assessment, 3) reduce risks and increase adaptive capacity, and 4) identify adaptation options: http://scc.ca.gov/2013/04/24/guidance-for-grantees
San Francisco Bay Conservation and Development Commission (BCDC)	*Climate Change Bay Plan Amendment* (2011)	Amends *Bay Plan* to include policies on climate change and sea level rise. Policies require: 1) a sea level rise risk assessment for shoreline planning and larger shoreline projects, and 2) if risks exist, the project must be designed to cope with flood levels by mid-century, and include a plan to address flood risks at end of century. Assessments are required to "identify all types of potential flooding, degrees of uncertainty, consequences of defense failure, and risks to existing habitat from proposed flood protection devices": http://www.bcdc.ca.gov/proposed_bay_plan/bp_amend_1-08.shtml

	Living with a Rising Bay: Vulnerability and Adaptation in San Francisco Bay and on its Shoreline (2011)	Provides the background staff report identifying vulnerabilities in the Bay Area's economic and environmental systems, as well as the potential impacts of climate change on public health and safety. The report provides the basis for all versions of the proposed findings and policies concerning climate change: http://www.bcdc.ca.gov/BPA/LivingWithRisingBay.pdf
California Department of Transportation (Caltrans)	*Estimating Sea Level for Project Initiation Documents* (2012)	Provides guidance on converting tidal datums and predicting future sea levels. http://www.dot.ca.gov/hq/row/landsurveys/SurveysManual/Estimating_Sea_Level_v1.pdf
	Guidance on Incorporating Sea Level Rise (2011)	Provides guidance on how to incorporate sea level rise concerns into programming and design of Caltrans projects. Includes screening criteria for determining whether to include SLR and steps for evaluating degree of potential impacts, developing adaptation alternatives, and implementing the adaptation strategies: http://www.dot.ca.gov/ser/downloads/sealevel/guide_incorp_slr.pdf
	Addressing Climate Change in Adaptation Regional Transportation Plans: A Guide for MPOs and RTPAs (2013)	Provides a clear methodology for regional agencies to address climate change impacts through adaptation of transportation infrastructure: http://www.camsys.com/pubs/FR3_CA_Climate_Change_Adaptation_Guide_2013-02-26_.pdf

Cal OES	*California Multi-Hazard Mitigation Plan* (SHMP 2013)	"The 2013 SHMP represents the state's primary hazard mitigation guidance document, and provides an updated and comprehensive description of California's historical and current hazard analysis, mitigation strategies, goals and objectives. Innovative features of the California hazard mitigation plan include an expanded discussion of climate change and adaptation strategies, a new and expanded section on volcanic hazards in the state, as well as significant mitigation initiatives, strategies and actions completed since adoption of the 2010 SHMP." http://hazardmitigation.calema.ca.gov/plan/state_multi-hazard_mitigation_plan_shmp
State Lands Commission	Application for Lease of State Lands	Requires assessment of climate change risks, and preference is given to projects that reduce climate change risks: http://www.slc.ca.gov/Forms/LMDApplication/LeaseApp.pdf
California State Parks	Sea level rise guidance (*in development*)	Will provide guidance to Park staff on how to assess impacts to parklands.
Groups of state agencies	California Climate Change Center's 3rd Assessment	Explores local and statewide vulnerabilities to climate change, highlighting opportunities for taking concrete actions to reduce climate-change impacts: http://climatechange.ca.gov/climate_action_team/reports/third_assessment/
	California Climate Adaptation Planning Guide (APG)	Provides a decision-making framework intended for use by local and regional stakeholders to aid in the interpretation of climate science and to develop a systematic rationale for reducing risks caused, or exacerbated, by climate change (2012): http://resources.ca.gov/climate/safeguarding/adaptation_policy_guide/

Appendix D

General LCP Amendment Processing Steps and Best Practices

Sea level rise is one of many topics that should be addressed in a Local Coastal Program (LCP) or LCP amendment. The Coastal Commission offers a *Local Coastal Program (LCP) Update Guide* that outlines the broad process for amending or certifying an LCP, including guidance for both Land Use Plans and Implementation Plans. It addresses major Coastal Act concerns, including public access, recreation and visitor serving facilities, water quality protection, ESHA and natural resources, agricultural resources, new development, archaeological and cultural resources, scenic and visual resources, coastal hazards, shoreline erosion and protective devices, energy and industrial development, and timberlands. Therefore, this *Sea Level Rise Policy Guidance* should be used in conjunction with the LCP Update Guide to perform complete LCP amendments or certifications. The following figure depicts the general LCP amendment process.

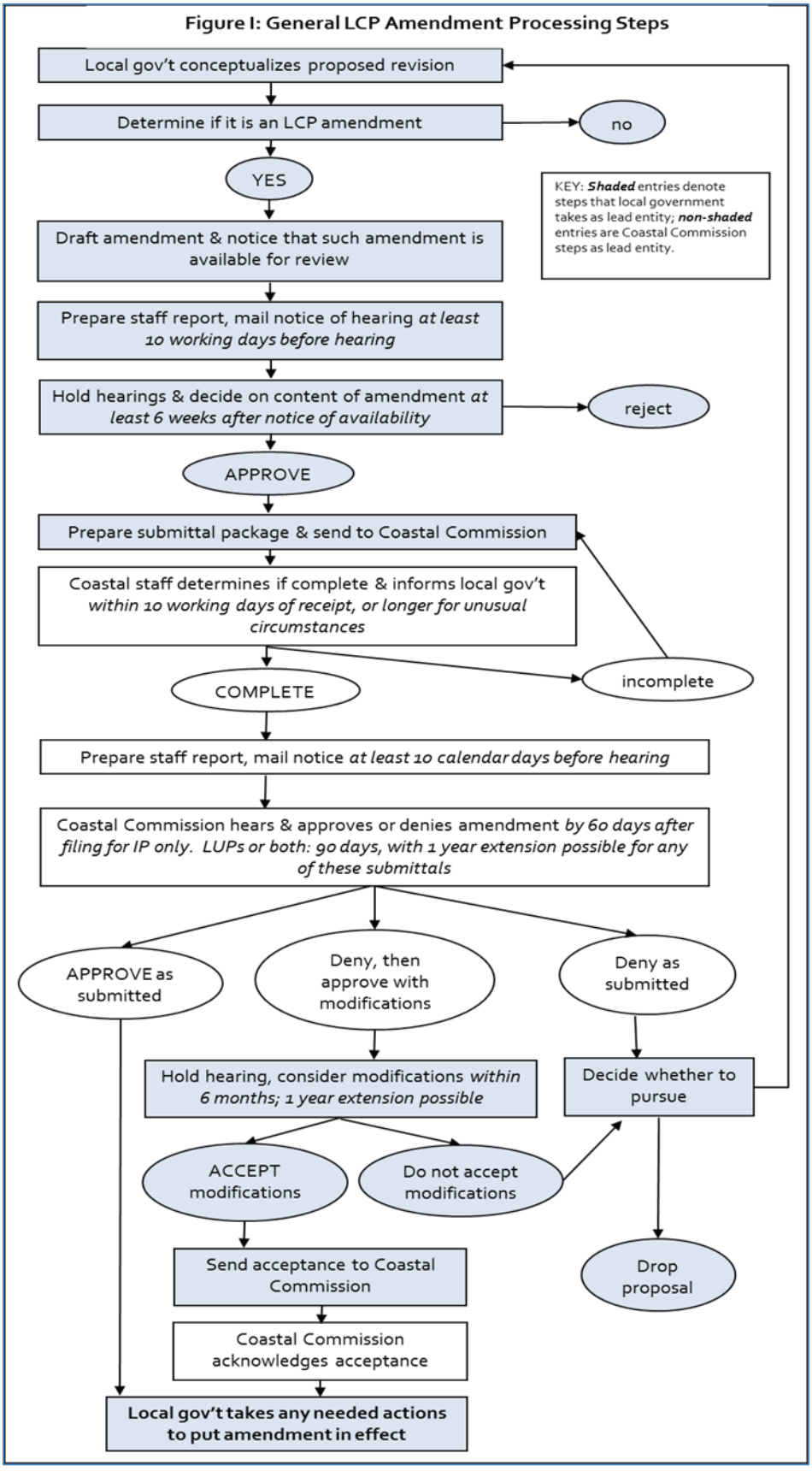
Figure I: General LCP Amendment Processing Steps
Local gov't conceptualizes proposed revision
Determine if it is an LCP amendment
no
YES
KEY: Shaded entries denote steps that local government takes as lead entity; non-shaded entries are Coastal Commission steps as lead entity.
Draft amendment & notice that such amendment is available for review
Prepare staff report, mail notice of hearing at least 10 working days before hearing
Hold hearings & decide on content of amendment at least 6 weeks after notice of availability
reject
APPROVE
Prepare submittal package & send to Coastal Commission
Coastal staff determines if complete & informs local gov't within 10 working days of receipt, or longer for unusual circumstances
incomplete
COMPLETE
Prepare staff report, mail notice at least 10 calendar days before hearing
Coastal Commission hears & approves or denies amendment by 60 days after filing for IP only. LUPs or both: 90 days, with 1 year extension possible for any of these submittals
APPROVE as submitted
Deny, then approve with modifications
Deny as submitted
Hold hearing, consider modifications within 6 months; 1 year extension possible
Decide whether to pursue
ACCEPT modifications
Do not accept modifications
Send acceptance to Coastal Commission
Drop proposal
Coastal Commission acknowledges acceptance
Local gov't takes any needed actions to put amendment in effect

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Appendix E

Funding Opportunities for LCP Planning and Implementation

Project Implementation Funds

The following table includes a list of grant funding available for implementation of sea level rise adaptation projects and programs. Much of this information was compiled by the Governor's Office of Emergency Services (Cal OES).

Grant Name	Agency	Purpose	Contact
Pre-Disaster Mitigation (PDM) Program	Administered by: Cal OES Funded by: US Department of Homeland Security, Federal Emergency Management Agency (FEMA)	Provides funds for hazard mitigation planning and projects on an annual basis. The PDM program was put in place to reduce overall risk to people and structures, while at the same time reducing reliance on federal funding if an actual disaster were to occur.	Cal OES http://www.caloes.ca.gov/cal-oes-divisions/hazard-mitigation/pre-disaster-flood-mitigation FEMA https://www.fema.gov/pre-disaster-mitigation-grant-program
Hazard Mitigation Grant (HMG) Program	Administered by: Cal OES Funded by: US Department of Homeland Security, Federal Emergency Management Agency (FEMA)	Provides grants to states and local governments to implement long-term hazard mitigation measures after a major disaster declaration. The purpose of the HMGP is to reduce the loss of life and property due to natural disasters and to enable mitigation measures to be implemented during the immediate recovery from a disaster.	Cal OES http://www.caloes.ca.gov/cal-oes-divisions/recovery/disaster-mitigation-technical-support/404-hazard-mitigation-grant-program FEMA https://www.fema.gov/hazard-mitigation-grant-program
Flood Mitigation Assistance (FMA) Program	Administered by: Cal OES Funded by: US Department of Homeland Security, Federal Emergency Management Agency (FEMA)	Provides grants to assist states and communities in implementing measures to reduce or eliminate the long-term risk of flood damage to buildings, manufactured homes, and other structures insurable under the NFIP.	Cal OES http://www.caloes.ca.gov/cal-oes-divisions/hazard-mitigation/pre-disaster-flood-mitigation FEMA https://www.fema.gov/flood-mitigation-assistance-program

Public Assistance (PA) Program	US Department of Homeland Security, Federal Emergency Management Agency (FEMA)	To provide supplemental Federal disaster grant assistance for debris removal, emergency protective measures, and the repair, replacement, or restoration of disaster-damaged, publicly owned facilities and the facilities of certain Private Non-Profit (PNP) organizations. The PA Program also encourages protection of these damaged facilities from future events by providing assistance for hazard mitigation measures during the recovery process.	FEMA https://www.fema.gov/public-assistance-local-state-tribal-and-non-profit
Community Development Block Grant (CDBG) Program	US Department of Housing and Urban Development	Program works to ensure decent affordable housing, to provide services to the most vulnerable in our communities, and to create jobs through the expansion and retention of businesses.	HUD http://portal.hud.gov/hudportal/HUD?src=/program_offices/comm_planning/communitydevelopment/programs
Watershed Surveys and Planning	US Department of Agriculture, Natural Resource Conservation Service	To provide planning assistance to Federal, state and local agencies for the development or coordination of water and related land resources and programs in watersheds and river basins.	NRCS http://www.nrcs.usda.gov/wps/portal/nrcs/main/national/programs/landscape/wsp/
Watershed Protection and Flood Prevention	US Department of Agriculture, Natural Resource Conservation Service	To provide technical and financial assistance in planning and executing works of improvement to protect, develop, and use of land and water resources in small watersheds.	NRCS http://www.nrcs.usda.gov/wps/portal/nrcs/main/national/programs/landscape/wfpo/
Land and Water Conservation Fund Grants	US Department of the Interior, National Park Service	To acquire and develop outdoor recreation areas and facilities for the general public, to meet current and future needs.	NPS http://www.nps.gov/lwcf/index.htm

SBA Disaster Loan Program	US Small Business Administration	SBA provides low-interest disaster loans to businesses of all sizes, private non-profit organizations, homeowners, and renters. SBA disaster loans can be used to repair or replace the following items damaged or destroyed in a declared disaster: real estate, personal property, machinery and equipment, and inventory and business assets.	SBA https://www.sba.gov/content/disaster-loan-program
Clean Water Act Section 319 Grants	US Environmental Protection Agency	To implement state and tribal non-point source pollution management programs, including support for non-structural watershed resource restoration activities.	EPA http://water.epa.gov/polwaste/nps/319hfunds.cfm
Flood Control Works/ Emergency Rehabilitation	US Department of Defense, Army Corps of Engineers	To assist in the repairs and restoration of public works damaged by flood, extraordinary wind, wave or water action.	USACE http://www.usace.army.mil/Missions/EmergencyOperations/NationalResponseFramework/FloodControl.aspx
Emergency Streambank and Shoreline Protection	US Department of Defense, Army Corps of Engineers	To prevent erosion damages to public facilities by the emergency construction or repair of streambank and shoreline protection works (33 CFR 263.25)	USACE http://www.mvr.usace.army.mil/BusinessWithUs/OutreachCustomerService/FloodRiskManagement/Section14.aspx
Small Flood Control Projects	US Department of Defense, Army Corps of Engineers	To reduce flood damages through small flood control projects not specifically authorized by Congress.	USACE www.usace.army.mil See also: https://www.cfda.gov/index?s=program&mode=form&tab=core&id=2216ee03c69db437c431036a5585ede6

Appendix F

Primary Coastal Act Policies Related to Sea Level Rise and Coastal Hazards

Legislative Findings Relating to Sea Level Rise

Section 30006.5 of the Coastal Act states (Legislative findings and declarations; technical advice and recommendations) states (emphasis added):

> *The Legislature further finds and declares that sound and timely scientific recommendations are necessary for many coastal planning, conservation, and development decisions and that the commission should, in addition to developing its own expertise in significant applicable fields of science, interact with members of the scientific and academic communities in the social, physical, and natural sciences so that the commission may receive technical advice and recommendations with regard to its decisionmaking, especially with regard to issues such as coastal erosion and geology, marine biodiversity, wetland restoration, the question of sea level rise, desalination plants, and the cumulative impact of coastal zone developments.*

Public Access and Recreation

Section 30210 of the Coastal Act (Access; recreational opportunities; posting) states:

> *In carrying out the requirement of Section 4 of Article X of the California Constitution, maximum access, which shall be conspicuously posted, and recreational opportunities shall be provided for all the people consistent with public safety needs and the need to protect public rights, rights of private property owners, and natural resource areas from overuse.*

Section 30211 of the Coastal Act (Development not to interfere with access) states:

> *Development shall not interfere with the public's right of access to the sea where acquired through use or legislative authorization, including, but not limited to, the use of dry sand and rocky coastal beaches to the first line of terrestrial vegetation.*

Section 30212 of the Coastal Act (New development projects) states:

> *(a) Public access from the nearest public roadway to the shoreline and along the coast shall be provided in new development projects except where: (1) it is inconsistent with public safety, military security needs, or the protection of fragile coastal resources, (2) adequate access exists nearby, or (3) agriculture would be adversely affected. Dedicated accessway shall not be required to be opened to public use until a public agency or private association agrees to accept responsibility for maintenance and liability of the accessway.*

Section 30214 of the Coastal Act (Implementation of public access policies; legislative intent) states:

> (*a) The public access policies of this article shall be implemented in a manner that takes into account the need to regulate the time, place, and manner of public access depending on the facts and circumstances in each case including, but not limited to, the following:*
>
> *(1) Topographic and geologic site characteristics.*
>
> *(2) The capacity of the site to sustain use and at what level of intensity.*

(3) The appropriateness of limiting public access to the right to pass and repass depending on such factors as the fragility of the natural resources in the area and the proximity of the access area to adjacent residential uses.

(4) The need to provide for the management of access areas so as to protect the privacy of adjacent property owners and to protect the aesthetic values of the area by providing for the collection of litter.

(b) It is the intent of the Legislature that the public access policies of this article be carried out in a reasonable manner that considers the equities and that balances the rights of the individual property owner with the public's constitutional right of access pursuant to Section 4 of Article X of the California Constitution. Nothing in this section or any amendment thereto shall be construed as a limitation on the rights guaranteed to the public under Section 4 of Article X of the California Constitution.

(c) In carrying out the public access policies of this article, the commission and any other responsible public agency shall consider and encourage the utilization of innovative access management techniques, including, but not limited to, agreements with private organizations which would minimize management costs and encourage the use of volunteer programs.

Section 30220 of the Coastal Act (Protection of certain water-oriented activities) states:

Coastal areas suited for water-oriented recreational activities that cannot readily be provided at inland water areas shall be protected for such uses.

Section 30221 of the Coastal Act (Oceanfront land; protection for recreational use and development**)** states:

Oceanfront land suitable for recreational use shall be protected for recreational use and development unless present and foreseeable future demand for public or commercial recreational activities that could be accommodated on the property is already adequately provided for in the area.

Section 30223 of the Coastal Act (Upland areas) states:

Upland areas necessary to support coastal recreational uses shall be reserved for such uses, where feasible.

Wetlands and Environmentally Sensitive Resources

Section 30231 of the Coastal Act (Biological productivity; water quality) states in part:

The biological productivity and the quality of coastal waters, streams, wetlands, estuaries, and lakes appropriate to maintain optimum populations of marine organisms and for the protection of human health shall be maintained and, where feasible, restored…

Section 30233 of the Coastal Act (Diking, filling or dredging; continued movement of sediment and nutrients) states:

> *(a) The diking, filling, or dredging of open coastal waters, wetlands, estuaries, and lakes shall be permitted in accordance with other applicable provisions of this division, where there is no feasible less environmentally damaging alternative, and where feasible mitigation measures have been provided to minimize adverse environmental effects, and shall be limited to the following:*

Section 30240 of the Coastal Act (Environmentally sensitive habitat areas; adjacent developments) states:

> *(a) Environmentally sensitive habitat areas shall be protected against any significant disruption of habitat values, and only uses dependent on those resources shall be allowed within those areas.*
>
> *(b) Development in areas adjacent to environmentally sensitive habitat areas and parks and recreation areas shall be sited and designed to prevent impacts which would significantly degrade those areas, and shall be compatible with the continuance of those habitat and recreation areas.*

Coastal Act Section 30121 defines “Wetland” as follows:

> *"Wetland" means lands within the coastal zone which may be covered periodically or permanently with shallow water and include saltwater marshes, freshwater marshes, open or closed brackish water marshes, swamps, mudflats, and fens.*

The California Code of Regulations Section 13577(b) of Title 14, Division 5.5, Article 18 defines “Wetland” as follows:

> *(1) Measure 100 feet landward from the upland limit of the wetland. Wetland shall be defined as land where the water table is at, near, or above the land surface long enough to promote the formation of hydric soils or to support the growth of hydrophytes, and shall also include those types of wetlands where vegetation is lacking and soil is poorly developed or absent as a result of frequent and drastic fluctuations of surface water levels, wave action, water flow, turbidity or high concentrations of salts or other substances in the substrate. Such wetlands can be recognized by the presence of surface water or saturated substrate at some time during each year and their location within, or adjacent to, vegetated wetlands or deep-water habitats. For purposes of this section, the upland limit of a wetland shall be defined as:*
>
> > *(A) the boundary between land with predominantly hydrophytic cover and land with predominantly mesophytic or xerophytic cover;*
> >
> > *(B) the boundary between soil that is predominantly hydric and soil that is predominantly nonhydric; or*
> >
> > *(C) in the case of wetlands without vegetation or soils, the boundary between land that is flooded or saturated at some time during years of normal precipitation, and land that is not.*
>
> *(2) For the purposes of this section, the term “wetland” shall not include wetland habitat created by the presence of and associated with agricultural ponds and reservoirs where:*

> *(A) the pond or reservoir was in fact constructed by a farmer or rancher for agricultural purposes; and*
>
> *(B) there is no evidence (e.g., aerial photographs, historical survey, etc.) showing that wetland habitat pre-dated the existence of the pond or reservoir. Areas with drained hydric soils that are no longer capable of supporting hydrophytes shall not be considered wetlands.*

In addition, Coastal Act Section 30107.5 defines “Environmentally sensitive area" as follows:

> *"Environmentally sensitive area" means any area in which plant or animal life or their habitats are either rare or especially valuable because of their special nature or role in an ecosystem and which could be easily disturbed or degraded by human activities and developments.*

Agricultural and Timber Lands

Section 30241 of the Coastal Act (Prime agricultural land; maintenance in agricultural production) states:

> *The maximum amount of prime agricultural land shall be maintained in agricultural production to assure the protection of the areas’ agricultural economy, and conflicts shall be minimized between agricultural and urban land uses…*

Section 30242 of the Coastal Act (Lands suitable for agricultural use; conversion) states:

> *All other lands suitable for agricultural use shall not be converted to nonagricultural uses unless (1) continued or renewed agriculture use is not feasible, or (2) such conversion would preserve prime agricultural land or concentrate development consistent with Section 30250. Any such permitted conversion shall be compatible with continue agricultural use on surrounding lands.*

Section 30243 of the Coastal Act (Productivity of soils and timberlands; conversions) states:

> *The long-term productivity of soils and timberlands shall be protected, and conversions of coastal commercial timberlands in units of commercial size to other uses or their division into units of noncommercial size shall be limited to providing for necessary timber processing and related facilities.*

Archaeological and Paleontological Resources

Section 30244 of the Coastal Act (Archaeological or paleontological resources) states:

> *Where development would adversely impact archaeological or paleontological resources as identified by the State Historic Preservation Officer, reasonable mitigation measures shall be required.*

Marine Resources

Section 30230 of the Coastal Act (Marine resources; maintenance) states:

> *Marine resources shall be maintained, enhanced, and where feasible, restored. Special protection shall be given to areas and species of special biological or economic significance. Uses of the marine environment shall be carried out in a manner that will sustain the biological productivity of coastal waters and that will maintain healthy populations of all species of marine organisms adequate for long-term commercial, recreational, scientific, and educational purposes.*

Section 30231 of the Coastal Act (Biological productivity; water quality) states:

> *The biological productivity and the quality of coastal waters, streams, wetlands, estuaries, and lakes appropriate to maintain optimum populations of marine organisms and for the protection of human health shall be maintained and, where feasible, restored through, among other means, minimizing adverse effects of waste water discharges and entrainment, controlling runoff, preventing depletion of ground water supplies and substantial interference with surface waterflow, encouraging waste water reclamation, maintaining natural vegetation buffer areas that protect riparian habitats, and minimizing alteration of natural streams.*

Section 30233 of the Coastal Act (Diking, filling or dredging; continued movement of sediment and nutrients) states:

> *(a) The diking, filling, or dredging of open coastal waters, wetlands, estuaries, and lakes shall be permitted in accordance with other applicable provisions of this division, where there is no feasible less environmentally damaging alternative, and where feasible mitigation measures have been provided to minimize adverse environmental effects…*
>
> *(d) Erosion control and flood control facilities constructed on watercourses can impede the movement of sediment and nutrients that would otherwise be carried by storm runoff into coastal waters. To facilitate the continued delivery of these sediments to the littoral zone, whenever feasible, the material removed from these facilities may be placed at appropriate points on the shoreline in accordance with other applicable provisions of this division, where feasible mitigation measures have been provided to minimize adverse environmental effects. Aspects that shall be considered before issuing a Coastal Development Permit for these purposes are the method of placement, time of year of placement, and sensitivity of the placement area.*

Section 30234 of the Coastal Act (Commercial fishing and recreational boating facilities**)** states:

> *Facilities serving the commercial fishing and recreational boating industries shall be protected and, where feasible, upgraded. Existing commercial fishing and recreational boating harbor space shall not be reduced unless the demand for those facilities no longer exists or adequate substitute space has been provided. Proposed recreational boating facilities shall, where feasible, be designed and located in such a fashion as not to interfere with the needs of the commercial fishing industry.*

Section 30234.5 of the Coastal Act (Economic, commercial, and recreational importance of fishing) states:

> *The economic, commercial, and recreational importance of fishing activities shall be recognized and protected.*

Coastal Development

Section 30250 of the Coastal Act (Location; existing developed area) states:

> *(a) New residential, commercial, or industrial development, except as otherwise provided in this division, shall be located within, contiguous with, or in close proximity to, existing developed areas able to accommodate it or, where such areas are not able to accommodate it, in other areas with adequate public services and where it will not have significant adverse effects, either individually or cumulatively, on coastal resources. In addition, land divisions, other than leases for agricultural uses, outside existing developed areas shall be permitted only where 50 percent of the usable parcels in the area have been developed and the created parcels would be no smaller than the average size of surrounding parcels.*
>
> *(b) Where feasible, new hazardous industrial development shall be located away from existing developed areas.*
>
> *(c) Visitor-serving facilities that cannot feasibly be located in existing developed areas shall be located in existing isolated developments or at selected points of attraction for visitors.*

Section 30251 of the Coastal Act (Scenic and visual qualities) states:

> *The scenic and visual qualities of coastal areas shall be considered and protected as a resource of public importance. Permitted development shall be sited and designed to protect views to and along the ocean and scenic coastal areas, to minimize the alteration of natural land forms, to be visually compatible with the character of surrounding areas, and, where feasible, to restore and enhance visual quality in visually degraded areas...*

Section 30253 the Coastal Act (Minimization of adverse impacts) states in part:

> *New development shall do all of the following:*
>
> *(a) Minimize risks to life and property in areas of high geologic, flood, and fire hazard.*
>
> *(b) Assure stability and structural integrity, and neither create nor contribute significantly to erosion, geologic instability, or destruction of the site or surrounding area or in any way require the construction of protective devices that would substantially alter natural landforms along bluffs and cliffs...*

Section 30235 of the Coastal Act (Construction altering natural shoreline) states:

> *Revetments, breakwaters, groins, harbor channels, seawalls, cliff retaining walls, and other such construction that alters natural shoreline processes shall be permitted when required to serve coastal-dependent uses or to protect existing structures or public*

beaches in danger from erosion, and when designed to eliminate or mitigate adverse impacts on local shoreline sand supply. Existing marine structures causing water stagnation contributing to pollution problems and fishkills should be phased out or upgraded where feasible.

Section 30236 of the Coastal Act (Water supply and flood control) states:

Channelizations, dams, or other substantial alterations of rivers and streams shall incorporate the best mitigation measures feasible, and be limited to (l) necessary water supply projects, (2) flood control projects where no other method for protecting existing structures in the flood plain is feasible and where such protection is necessary for public safety or to protect existing development, or (3) developments where the primary function is the improvement of fish and wildlife habitat.

Ports

Section 30705 of the Coastal Act (Diking, filling or dredging water areas) states:

(a) Water areas may be diked, filled, or dredged when consistent with a certified port master plan only for the following: …

(b) The design and location of new or expanded facilities shall, to the extent practicable, take advantage of existing water depths, water circulation, siltation patterns, and means available to reduce controllable sedimentation so as to diminish the need for future dredging.

(c) Dredging shall be planned, scheduled, and carried out to minimize disruption to fish and bird breeding and migrations, marine habitats, and water circulation. Bottom sediments or sediment elutriate shall be analyzed for toxicants prior to dredging or mining, and where water quality standards are met, dredge spoils may be deposited in open coastal water sites designated to minimize potential adverse impacts on marine organisms, or in confined coastal waters designated as fill sites by the master plan where such spoil can be isolated and contained, or in fill basins on upland sites. Dredge material shall not be transported from coastal waters into estuarine or fresh water areas for disposal.

Section 30706 of the Coastal Act (Fill) states:

In addition to the other provisions of this chapter, the policies contained in this section shall govern filling seaward of the mean high tide line within the jurisdiction of ports:

(a) The water area to be filled shall be the minimum necessary to achieve the purpose of the fill.

(b) The nature, location, and extent of any fill, including the disposal of dredge spoils within an area designated for fill, shall minimize harmful effects to coastal resources, such as water quality, fish or wildlife resources, recreational resources, or sand transport systems, and shall minimize reductions of the volume, surface area, or circulation of water.

(c) The fill is constructed in accordance with sound safety standards which will afford reasonable protection to persons and property against the hazards of unstable geologic or soil conditions or of flood or storm waters.

(d) The fill is consistent with navigational safety.

Section 30708 of the Coastal Act (Location, design and construction of port related developments) states:

All port-related developments shall be located, designed, and constructed so as to:

(a) Minimize substantial adverse environmental impacts.

(b) Minimize potential traffic conflicts between vessels.

(c) Give highest priority to the use of existing land space within harbors for port purposes, including, but not limited to, navigational facilities, shipping industries, and necessary support and access facilities.

(d) Provide for other beneficial uses consistent with the public trust, including, but not limited to, recreation and wildlife habitat uses, to the extent feasible.

(e) Encourage rail service to port areas and multicompany use of facilities.

Public Works Facilities

According to Coastal Act Section 30114, public works facilities include:

(a) All production, storage, transmission, and recovery facilities for water, sewerage, telephone, and other similar utilities owned or operated by any public agency or by any utility subject to the jurisdiction of the Public Utilities Commission, except for energy facilities.

(b) All public transportation facilities, including streets, roads, highways, public parking lots and structures, ports, harbors, airports, railroads, and mass transit facilities and stations, bridges, trolley wires, and other related facilities. For purposes of this division, neither the Ports of Hueneme, Long Beach, Los Angeles, nor San Diego Unified Port District nor any of the developments within these ports shall be considered public works.

(c) All publicly financed recreational facilities, all projects of the State Coastal Conservancy, and any development by a special district.

(d) All community college facilities.

Greenhouse Gas Emissions Reduction

Section 30250(a) of the Coastal Act (Location, existing developed areas states) in part:

(a) New residential, commercial, or industrial development, except as otherwise provided in this division, shall be located within, contiguous with, or in close proximity to, existing developed areas able to accommodate it or, where such areas are not able to accommodate it, in other areas with adequate public services and where it will not have

significant adverse effects, either individually or cumulatively, on coastal resources. In addition, land divisions, other than leases for agricultural uses, outside existing developed areas shall be permitted only where 50 percent of the usable parcels in the area have been developed and the created parcels would be no smaller than the average size of surrounding parcels.

Section 30252 of the Coastal Act (Maintenance and enhancement of public access) states:

The location and amount of new development should maintain and enhance public access to the coast by (1) facilitating the provision or extension of transit service, (2) providing commercial facilities within or adjoining residential development or in other areas that will minimize the use of coastal access roads, (3) providing nonautomobile circulation within the development, (4) providing adequate parking facilities or providing substitute means of serving the development with public transportation, (5) assuring the potential for public transit for high intensity uses such as high-rise office buildings, and by (6) assuring that the recreational needs of new residents will not overload nearby coastal recreation areas by correlating the amount of development with local park acquisition and development plans with the provision of onsite recreational facilities to serve the new development.

Section 30253(d) of the Coastal Act (Minimization of adverse impacts) states in part:

New Development shall:

(d) Minimize energy consumption and vehicle miles traveled….

Appendix G

Coastal Commission Contact Information

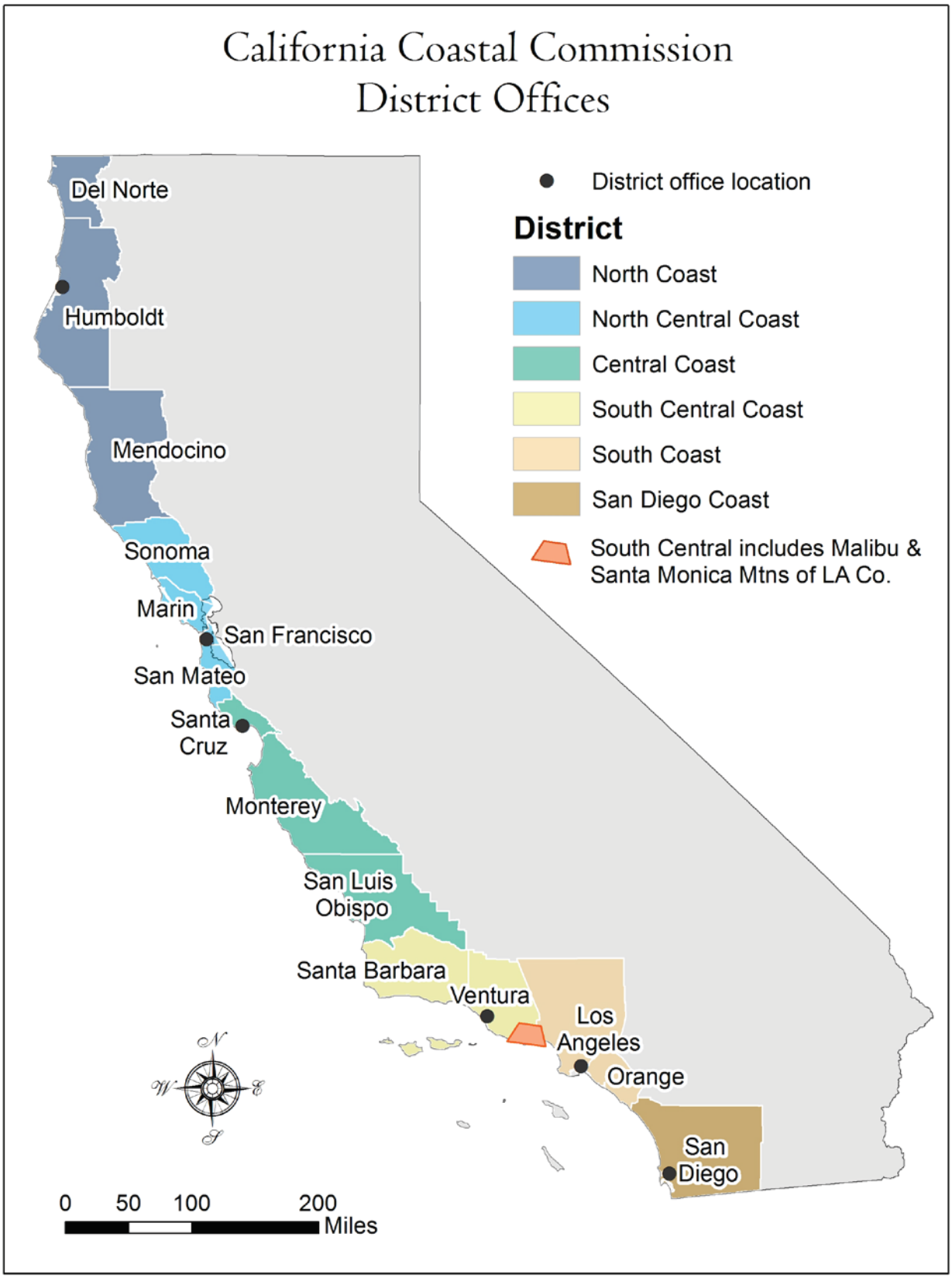

Figure G-1. Location of Coastal Commission offices

COASTAL COMMISSION DISTRICT OFFICE CONTACT INFORMATION

North Coast (Del Norte, Humboldt, Mendocino Counties)
(707) 826-8950

Headquarters and North Central Coast (Sonoma, Marin, San Francisco, San Mateo Counties)
(415)-904-5200

Central Coast (Santa Cruz, Monterey, San Luis Obispo Counties)
(831) 427-4863

South Central Coast (Santa Barbara and Ventura Counties, and the Malibu portion of Los Angeles County)
(805) 585-1800

South Coast (Los Angeles (except Malibu) and Orange Counties)
(562) 590-5071

San Diego (San Diego County)
(619) 767-2370

COASTAL COMMISSION STAFF SEA LEVEL RISE TEAM

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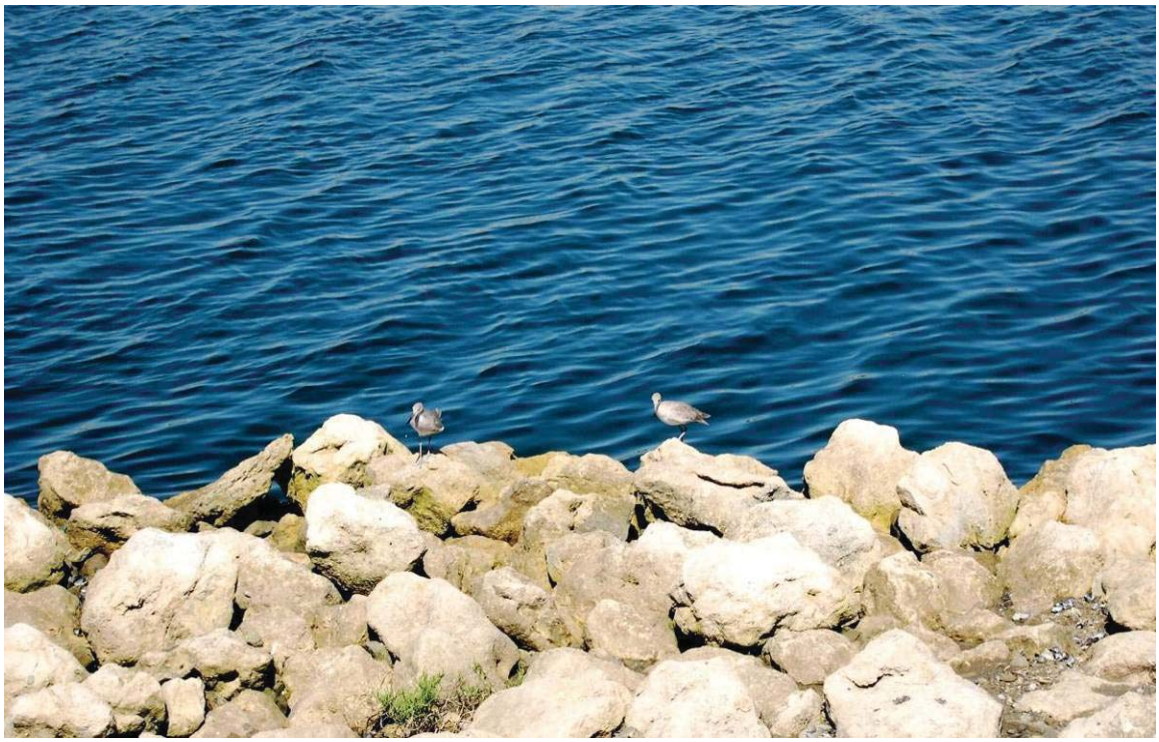
APPENDIX M
BALLONA ESTUARY & SEPELVEDA CHANNEL BACTERIA TMDL, COORDINATED MONITORING PLAN

BALLONA CREEK, BALLONA ESTUARY, & SEPULVEDA CHANNEL BACTERIA TMDL

COORDINATED MONITORING PLAN



PREPARED BY THE MONITORING PLAN SUB-COMMITTEE
CITY OF LOS ANGELES, CHAIR

SUBMITTED
April 23, 2008

ACKNOWLEDGEMENT

The Coordinated Monitoring Plan (CMP) was developed by the City of Los Angeles (Primary Jurisdiction), County of Los Angeles (represented by Department of Public Works – Watershed Management Division), Cities of Culver City, Beverly Hills, West Hollywood, Inglewood, Santa Monica and California Department of Transportation (Caltrans).

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APPENDIX M	Participating Organizations Contacts (Monitoring)

LIST OF ACRONYMS

ALERT	Automatic Local Evaluation in Real-Time
APHA	American Public Health Association
AWWA	American Water Works Association
BCB	Ballona Creek Bacteria
CA DOHS	California Department of Health Services
Cal/OSHA	California Office of Occupational Safety and Health Administration
CalTrans	California Department of Transportation
CA DOHS	California Department of Health Services
CFU	Colony Forming Unit
CHP	Chemical Hygiene Plan
CMP	Coordinated Monitoring Plan
COC	Chain of Custody
CSV	Comma Separated Value
CWA	Clean Water Act
DMR	Discharge Monitoring Report
ELAP	Environmental Laboratory Accreditation Program
EMD	Environmental Monitoring Division (LA City)
EPA	Environmental Protection Agency
GIS	Geographic Information System
ICSD	Information and Control System Division (LA City)
LREC-1	Limited Water Contact Recreation
LACDPW	Los Angeles County Department of Public Works
LACSD	Los Angeles County Sanitation Districts
LARWQCB	Los Angeles Regional Water Quality Control Board
LIMS	Laboratory Information Management System
MPN	Most Probable Number
NIST	National Institute of Standards and Technology
NPDES	National Pollutant Discharge Elimination System
PE	Performance Evaluation
QA/QC	Quality Assurance/Quality Control
REC-1	Water Contact Recreation
REC-2	Non Contact Recreation
RPD	Relative Percentage Difference
SOP	Standard Operating Procedure
S & T	Status and Trends Monitoring Program (LA City)
TMDL	Total Maximum Daily Loads
WLA	Waste Load Allocations
WP	Water Pollution
WPCF	Water Pollution Control Federation
WPD	Watershed Protection Division (LA City)

1.0 EXECUTIVE SUMMARY

The Ballona Creek, Sepulveda Channel, and Ballona Estuary were listed on the State's 1998 303(d) list as impaired due to exceedance of total and/or fecal coliform water quality standards. To address the high bacteria concentrations in the Creek and its tributaries, the Los Angeles Regional Water Quality Control Board (Regional Board) on June 8, 2006, adopted the Total Maximum Daily Loads for Bacterial Indicator Densities in Ballona Creek, Ballona Estuary, and Sepulveda Channel (Bacteria TMDL). The Bacteria TMDL subsequently became effective on April 27, 2007 after approval by the U.S. Environmental Protection Agency (USEPA). This TMDL has multi-part numeric targets based on the updated bacteria objectives for marine and fresh waters designated for contact recreation (REC-1), and fresh waters with Limited REC-1 and non-contact water recreation (REC-2) beneficial use designations.

The Bacteria TMDL identifies the Responsible Jurisdictions and Agencies as the Cities of Los Angeles, Culver City, Beverly Hills, Inglewood, West Hollywood, Santa Monica, County of Los Angeles, and California Department of Transportation (Caltrans). The City of Los Angeles is the Primary Jurisdiction as it controls the majority of the land area in the watershed.

The Responsible Jurisdictions and Responsible Agencies are required to submit a comprehensive bacteria water quality monitoring plan for the Ballona Creek Watershed (Coordinated Monitoring Plan or CMP) to the Regional Board for approval by April 27, 2008, 12 months after the effective date of the Bacteria TMDL. Development and submittal of this document is to satisfy this requirement of the Bacteria TMDL.

Coordinated Monitoring Plan (CMP) Development

The CMP was developed by the Bacteria TMDL Monitoring Plan Sub-Committee. The Sub-Committee is chaired by the City of Los Angeles, the Primary Jurisdiction. The other members are the Responsible Jurisdictions and Responsible Agencies as designated in the Bacteria TMDL.

The CMP has three objectives:

1. To characterize existing water quality based on applicable bacteria water quality objectives and;
2. To assess compliance with the waste load allocations in the Bacteria TMDL and;
3. To provide data to support re-evaluations that will be made when the Bacteria TMDL is scheduled for reconsideration on April 27, 2011, four years after the effective date of the Bacteria TMDL.

Requirements of the Bacteria TMDL Coordinated Monitoring Plan

a) Ambient Monitoring

Ambient monitoring of water quality conditions will begin six months after the Regional Board's formal approval of the CMP and conclude at the first compliance deadline in

each impaired reach and at the confluences of each tributary. As stated in the TMDL, on-going monitoring efforts by the City of Los Angeles and County of Los Angeles within the Ballona Creek watershed may fulfill this requirement; however, all responsible jurisdictions and responsible agencies are ultimately accountable for ensuring that these monitoring requirements are met. Prior to the first compliance deadline weekly ambient monitoring will be conducted at the CMP-specified effectiveness monitoring locations found in **Table 3.1** and *Section 3.2*.

b) TMDL Effectiveness Monitoring

The TMDL effectiveness monitoring program shall be conducted to assess attainment of the allowable exceedances for Ballona Creek, Ballona Estuary, Sepulveda Channel, and the Waste Load Allocations (WLAs) for the tributaries. As stated in the TMDL:

If the number of exceedance days is greater than the allowable number of exceedance days in the REC-1 and LREC-1 waters, and/or the frequency of exceedance is greater than 10% in the REC-2 waters, the responsible jurisdictions and/or responsible agencies shall be considered not attaining the TMDLs and/or assigned allocations (non-attaining). Responsible jurisdictions or agencies will be considered attaining TMDLs and/or assigned allocations based upon the results of an investigation that at minimum shows single sample events meet bacteria water quality objectives through daily sampling results at the existing monitoring location.

Sampling Locations and Schedule

The implementation of the CMP will begin six months following its formal approval by the Regional Board with monitoring at eight (8) sites identified in the CMP. Detailed descriptions of each site can be found in **Section 3.2**.

Accelerated Sampling following Elevated Bacterial Levels (Exceedances)

For the summer dry-weather period and the winter dry-weather periods during effectiveness monitoring, accelerated sampling will be conducted as a result of single-sample exceedances. Locations monitored weekly will be subject to accelerated monitoring, at 48 hours after the initial bacterial exceedance and, if the 48-hour sample exceeds, sampling also will occur at 96 hours following the initial bacterial exceedance. All location-required indicator bacteria, not just the exceeding indicator, will be analyzed during accelerated testing.

Analytical Methodology

Samples will be tested for specific indicator bacteria (i.e., total coliforms, fecal coliforms and/or *E. coli*, and enterococcus) whose presence indicates that enteric pathogenic microorganisms also may also be present. Approved sampling and analytical procedures will be used as described in *Appendices D and G*. Sampling and analytical procedures are to be followed as specified in "Standard Methods for the Examination of Water and Wastewater", 18^{th} – 20^{th}edition, 1992, 1998 respectively, APHA, AWWA, WPCF, Washington, DC, and "Microbiological Methods for Monitoring the Environment, Water, and Wastes", EPA-600/8-78-017.

Data Management and Reporting

Electronically-formatted data will be archived and submitted to the responsible agencies and the Regional Board promptly after the data become available, and electronic copies of the monthly reports will be distributed to the responsible agencies.

2.0 INTRODUCTION

This monitoring proposal is submitted to fulfill the 12-month requirement for developing a Coordinated Monitoring Plan for the Ballona Creek, Ballona Estuary, and Sepulveda Channel Bacteria Total Maximum Daily Loads (BC Bacteria TMDL). For reference, the TMDL Regional Water Quality Control Plan (Basin Plan) amendments can be found in *Appendix K* of this document. All BC Bacteria TMDL documents, including the staff report, can be found on the Los Angeles Regional Water Quality Control Board's (LARWQCB) website at http://www.waterboards.ca.gov/losangeles/.

2.1 Background

Federal Regulations under the Clean Water Act (CWA) require states to develop a list of impaired waters and pollutants for which they are impaired, also known as the 303(d) List. The States must then establish the capacity of the water body to assimilate the impairing pollutants. These criteria are done in the form of the pollutant TMDL, which defines that the water body can still receive pollutant loads up to the water quality objectives necessary to protect beneficial uses (e.g., REC-1, REC-2, and LREC-1). Waste Load Allocations from point sources and load allocations from non-point sources must be reduced as needed according to the schedule set in the TMDL to meet TMDL compliance for the water body. The TMDL is incorporated as an amendment to the regional Basin Plan.

Ballona Creek, Ballona Estuary, and Sepulveda Channel were designated as impaired by the State of California and included on California's 2002 and 1998 CWA §303(d) List of Impaired Waters. Segments of the Ballona Creek, Ballona Estuary, and Sepulveda Channel are listed for high coliform counts. High bacterial loading of these water bodies may result in impairments of the water contact recreation (REC-1) beneficial use of Ballona Estuary[1] and Sepulveda Channel, limited water contact recreation (LREC-1) beneficial use of Ballona Creek Reach 2[2], and non-contact recreation (REC-2) beneficial use of Ballona Creek Reach 1[3] (**Table 2.1**). Recreating in waters with elevated bacterial indicator densities has long been associated with adverse human health effects.

[1] Ballona Estuary is from Centinela Avenue to the Pacific Ocean for 3.5 miles and its lower portion runs parallel to the main channel of Marina del Rey.
[2] Ballona Creek Reach 2 (Ballona Creek to Estuary) is approximately 4 miles from National Boulevard to Centinela Avenue.
[3] Ballona Creek Reach 1 is a 2-mile stretch from Cochran Avenue to National Boulevard.

Table 2.1 Ballona Creek Beneficial Uses

Water Body	Beneficial Use
Ballona Estuary	REC-1 Marine Water
Sepulveda Channel	REC-1 Fresh Water
Ballona Creek Reach 2	LREC-1 Fresh Water
Ballona Creek Reach 1	REC-2 Fresh Water

There are several historical or existing sites monitored by the Los Angeles County Department of Public Works (LACDPW), City of Los Angeles Watershed Protection Division (WPD), and City of Los Angeles Environmental Monitoring Division (EMD) in Ballona Creek, Ballona Estuary, and its tributaries.

Beginning in early 2001, the City of Los Angeles, Department of Public Works, Bureau of Sanitation, WPD, under its Status and Trends Monitoring Program (S&T), began monitoring at four (4) locations along the main channel of Ballona Creek for bacteria, metals, and other pollutants. In 2002 the Status and Trends Program was extended to include four (4) tributary monitoring locations. In addition, LACDPW, as part of the Los Angeles County Municipal Stormwater Permit, under its Core Monitoring Program, conducts sampling within the Ballona Creek watershed. The County's Core Monitoring Program is comprised of one permanent mass emission station (S01) within the main channel, six tributary locations, five estuary locations, and one bioassessment location. During the period of 2005-2006, LACDPW ended the monitoring activities for the six mass emission sites located on tributaries to the main channel of Ballona Creek. Currently, only station S01 is monitored for three storm and two dry-weather events.

2.2 Ballona Creek Watershed Setting

The Ballona Creek watershed is the largest sub-watershed within the Santa Monica Bay Watershed Management Area, and is comprised of West Los Angeles, Westwood Village, Culver City, Hollywood, Cienega, and Windsow Hills sub-watersheds as defined by the LARWQCB. The combined size of the six sub-watersheds is approximately 82,878 acres[4]; however, 13 acres of National Park Service land and 414 acres of miscellaneous State and Federal lands are currently excluded from the LARWQCB-defined jurisdictional group. The LARWQCB recommended that these areas be excluded at this time since they will be covered by separate NDPES permits issued by the LARWQCB. This leaves 82,451 acres as the effective watershed area[5]. The effective watershed area falls under the jurisdiction of eight agencies. (**Table 2.2**)

[4] Area breakdown was generated with GIS using data from LARWQCB.
[5] The overall effective watershed area may change depending on how the Regional Board decides to enforce National Parks Service and miscellaneous State and Federal areas to comply with the TMDLs.

Table 2.2 Ballona Creek Jurisdictional Group

Responsible Agencies	Land area	
City of Los Angeles (lead)	67,053	acres
County of Los Angeles	3,928	acres
City of Beverly Hills	3,630	acres
City of Culver City	3,234	acres
City of Inglewood	1,934	acres
City of West Hollywood	1,201	acres
City of Santa Monica	265	acres
Caltrans	1,206	acres
Total	82,451	acres

Ballona Creek flows as an open channel for approximately 10 miles from Los Angeles (South of Hancock Park) through Culver City, reaching the Santa Monica Bay just south of Marina del Rey. Tributaries of the Creek and Estuary include Centinela Creek, Sepulveda Channel, Benedict Canyon Channel, and numerous other storm drains. The transition between the Creek and Estuary is considered to occur at Centinela Boulevard; Ballona Creek above Centinela Boulevard is concrete-lined and Ballona Creek below Centinela Boulevard is soft bottom.

2.3 Waste Load Allocation Targets

The TMDL has a multi-part numeric target based on four bacteriological parameters: total coliform density, enterococcus density, fecal coliform density, and *Escherichia coli* (*E. coli)* density. All bacteria densities shall be reported as the number of bacteria counted in 100 milliliters of water sampled. These numerical targets and the corresponding waste load allocations have been set based on the Los Angeles Basin Plan objectives for water contact recreation (REC-1), limited water contact recreation (LREC-1), and water non-contact recreation (REC-2) uses.

The BC Bacteria TMDL specifies three separate periods for compliance purposes, each with specific requirements. The periods are summer dry-weather (April 1 to October 31), winter dry-weather (November 1 to March 31), and wet-weather days (defined as days of $\geq$ 0.1 inches of precipitation and the three days following the end of the rain event).

Waste load allocations in the Ballona Creek TMDLs are expressed as an allowed number of exceedance days. The number of allowable exceedance days at a given location is determined by the number of projected exceedance days during the 90th percentile year at either the designated reference site or historically at the location in question, whichever is lower. Allowable exceedance days, as determined by the reference site method, relative to a weekly monitoring schedule are shown in **Table 2.3 and Table 2.4.**

Table 2.3 Summary of waste load allocations in Ballona Creek, Ballona Estuary, and Sepulveda Channel by Reach.

Time Period	Ballona Estuary, Ballona Creek Reach 2, and Sepulveda Channel [1]	Ballona Creek Reach 1 [2]
Summer Dry-Weather (April 1 to October 31)	Zero (0) exceedance days based on the applicable Single Sample Bacteria Water Quality Objectives	No more than 10% of the Single Sample Bacteria Water Quality Objectives
	Zero (0) exceedance days based on the Rolling 30-Day Geometric Mean Bacteria Water Quality Objectives	Zero (0) exceedance days based on the Rolling 30-Day Geometric Mean Bacteria Water Quality Objectives
Winter Dry-Weather (November 1-March 31)	Three (3) exceedance days based on the applicable Single Sample Bacteria Water Quality Objective[4]	No more than 10% of the Single Sample Bacteria Water Quality Objectives
	Zero (0) exceedance days based on the Rolling 30-Day Geometric Mean Bacteria Water Quality Objectives	Zero (0) exceedance days based on the Rolling 30-Day Geometric Mean Bacteria Water Quality Objectives
Wet-Weather (days with ≥0.1 inch of rain + 3 days following the rain event)	Seventeen (17)[3] exceedance days based on the applicable Single Sample Bacteria Water Quality Objectives[4]	No more than 10% of the Single Sample Bacteria Water Quality Objectives
	Zero (0) exceedance days based on the Rolling 30-Day Geometric Mean Bacteria Water Quality Objectives.	Zero (0) exceedance days based on the Rolling 30-Days Geometric Mean Bacteria Water Quality Objectives

[1] Exceedance days for Ballona Estuary based on REC-1 marine water numeric targets; for Ballona Creek Reach 2 based on LREC-1 freshwater numeric targets; and for Sepulveda Channel, based on fresh water REC-1 numeric targets

[2] Exceedance frequency for Ballona Creek Reach 1 based on freshwater REC-2 numeric targets

[3] In Reach 2, the greater of the allowable exceedance days under the reference system approach or high flow suspension shall apply

[4] As set forth by the SMBB CMP the maximum allowable number of exceedance days per year based on the reference system during dry weather is scaled back to one (1) day per year based on weekly sampling and the maximum allowable number of exceedance days based on the reference system during year-round wet weather is scaled back accordingly to three (3) exceedance days per year based on weekly sampling.

Table 2.4 Summary of waste load allocations and load allocations for Ballona Creek Tributaries

Tributary	**Point of Application**	**Water Quality Objectives**	**Waste Load Allocation** (No. exceedance days)
Ballona Creek Reach 1	At confluence with Reach 2	LREC-1 Freshwater	For single sample objectives: *(0) summer dry-weather,* *(3) winter dry-weather,* *(17*) wet-weather* For geometric mean objectives: *(0) for all periods*
Benedict Canyon Channel	At confluence with Reach 2	LREC-1 Freshwater	For single sample objectives: *(0) summer dry-weather,* *(3) winter dry-weather,* *(17*) wet-weather* For geometric mean objectives: *(0) for all periods*
Ballona Creek Reach 2	At confluence with Ballona Estuary	REC-1 Marine water	For single sample objectives: *(0) summer dry-weather,* *(3) winter dry-weather,* *(17) wet-weather* For geometric mean objectives: *(0) for all periods*
Centinela Creek	At confluence with Ballona Estuary	REC-1 Marine water	For single sample objectives: *(0) summer dry-weather,* *(3) winter dry-weather,* *(17) wet-weather* For geometric mean objectives: *(0) for all periods*
Del Rey Lagoon	At confluence with Ballona Estuary	REC-1 Marine water	For single sample objectives: *(0) summer dry-weather,* *(3)winter dry-weather,* *(17) wet-weather* For geometric mean objectives: *(0) for all periods*

*At the confluence with Reach 2, the greater of the allowable exceedance days under the reference system approach or high flow suspension shall apply. Sepulveda Channel was not assigned a waste load allocation at its confluence with Reach 2 since the TMDL requires the more stringent REC-1 objectives to be met in this water body, which should lead to the attainment of the less stringent LREC-1 objectives of the downstream reach.

2.3.1 Single Sample Limits

The Single Sample Limits apply throughout the year, and are shown in **Table 2.5**

Table 2.5 Single Sample Limits

Marine Waters Designated for Water Contact Recreation (REC-1)	
Indicator	**Number of bacteria/100mL**
Total Coliform	10,000
Fecal Coliform	400
Enterococcus	104
Total Coliform density*	Fecal-to-Total Coliform ratio*
Fresh Waters Designated for Water Contact Recreation (REC-1)	
Indicator	**Number of bacteria/100mL**
E. coli	235
Fecal Coliform	400
Fresh Waters Designated for Limited Water Contact Recreation (LREC-1)	
Indicator	**Number of bacteria/100mL**
E. coli	576
Fecal Coliform	not assigned
Fresh Waters Designated for Water Non-Contact Recreation (REC-2)	
Indicator	**Number of bacteria/100mL**
E. coli	-
Fecal Coliform	4000

* Total coliform density shall not exceed 1,000/100mL, if the ratio of fecal-to-total coliform exceeds 0.1

There are a certain number of exceedance days allowed for single sample targets for summer dry-weather, winter dry-weather, and wet-weather days. The number of allowable exceedance days is established using a "reference system/anti-degradation approach," which is based on historical exceedance levels at existing monitoring locations, including a local reference beach within the Santa Monica Bay coastal watershed (Leo Carrillo State Beach). The maximum number of allowable exceedance days for REC-1, LREC-1 and REC-2 waters are shown in Table 2.3 and Table 2.4 (pages 8-9).

2.3.2 Rolling 30-day Geometric Mean Limits

The Rolling 30-day Geometric Mean Limits apply through the year, and are shown in **Table 2.6**

Table 2.6 Geometric Mean Limits

Marine Waters Designated for Water Contact Recreation (REC-1)	
Indicator	**Number of bacteria/100mL**
Total Coliform	1,000
Fecal Coliform	200
Enterococcus	35
Fresh Waters Designated for Water Contact Recreation (REC-1)	
Indicator	**Number of bacteria/100mL**
E. coli	126
Fecal Coliform	200
Fresh Waters Designated for Limited Water Contact Recreation (LREC-1)	
Indicator	**Number of bacteria/100mL**
E. coli	126
Fecal Coliform	200
Fresh Waters Designated for Water Non-Contact Recreation(REC-2)	
Indicator	**Number of bacteria/100mL**
E. coli	-
Fecal Coliform	2000

The Rolling 30-Day Geometric Mean is calculated as the 30^{th} root of the product of 30 numbers using the bacterial densities over the most recent 30 days.

The Geometric Mean Limits may not be exceeded at any time. The rolling 30-day geometric means will be calculated on each day, regardless of whether a weekly or daily schedule is selected. If weekly sampling is conducted each test result will supersede the previous result and be assigned to the remaining days of the week until the next sample is collected. Only dry-weather data are to be used to calculate geometric means; wet-weather data will be excluded from this calculation until single sample limits for wet-weather become effective.

The Rolling 30-Day Geometric Mean calculation may change. Based on recent communication with the Regional Board, we understand the method of calculating the daily Rolling 30-Day Geometric Mean proposed above has been deemed inappropriate and may be revised.

The TMDL will be implemented in two phases over a ten-year period. For the first phase, within six years of the effective date of the TMDL, the allowable number of summer dry-weather, winter dry-weather exceedance days, and the rolling 30-day

geometric mean targets must be achieved. For the second phase, within 10 years of the effective date of the TMDL (or by July 15, 2021 if the Integrated Water Resource Approach is implemented), the allowable number of wet-weather exceedance days and rolling 30-day geometric mean targets must be achieved.

2.4 Coordinated Monitoring Plan Development

This monitoring plan was developed by the Ballona Creek Monitoring Plan Sub-Committee, which was chaired by the City of Los Angeles (*Appendix M*).

In early 2007 the Ballona Jurisdictional Group began gathering information and meeting with representatives of the various agencies that had historically conducted monitoring within Ballona Creek watershed; namely the City of Los Angeles Bureau of Sanitation and the Los Angeles County Department of Public Works. During development of the CMP, input from the Regional Board, Santa Monica Bay Keeper, and Heal the Bay was sought and incorporated in this document. The first draft of the CMP was completed in January 2008 and presented to the Regional Board and non-governmental organizations. The final draft was submitted to the Regional Board in April 2008.

2.5 Requirements of Coordinated Monitoring Plan

As stated in the Ballona Creek, Ballona Estuary, and Sepulveda Channel Bacteria TMDL:

"Responsible jurisdictions and responsible agencies must submit, for Regional Board approval, a comprehensive bacteria water quality monitoring plan for the Ballona Creek Watershed [within twelve months of the effective date]. The plan must be approved by the Executive Officer before the monitoring data can be considered during the implementation of the TMDL. The plan must provide for analyses of all applicable bacteria indicators for which the Basin Plan and subsequent amendments have established objectives. The plan must also include a minimum of two sampling locations in Ballona Estuary and Ballona Creek (Reach 2), at least one location in Ballona Creek (Reach 1) and Sepulveda Channel, at the confluence with Centinela Creek and Benedict Canyon Channel, and similar monitoring at the connecting tide gates of Del Rey Lagoon."

The City of Los Angeles is the Responsible Agency for Del Rey Lagoon; therefore the Del Rey Lagoon requirement is not included in this CMP.

3.0 MONITORING SITES

For the purpose of this TMDL, eight (8) monitoring locations (**Table 3.1** and ***Figure 1)*** are being proposed. Four of these locations are currently being monitored by Los Angeles County Department of Public Works and/or by City of Los Angeles WPD and EMD as a part of its Status & Trends Program. The other four sites are new, or in close proximity to a historical site. *Appendix B* provides a summary of geographic data.

3.1 Site Selection Guidelines

The eight (8) sampling sites (**Table 3.1**) have been selected by all responsible agencies in the Jurisdictional Group using the following set of guidelines:

1. Sampling shall be conducted weekly at locations specified in Attachment A to Resolution No. 2006-011, page 8.
2. Monitoring locations shall be located at or close to the boundary of two reaches.
3. Monitoring locations shall have safe access for sampling.

Table 3.1 Summary of effectiveness monitoring sites

Station ID	BCB-1	BCB-2	BCB-3	BCB-4	BCB-5	BCB-6	BCB-7	BCB-8
Station Name	WASHINGTON	DUQUESNE	BENEDICT CANYON	CULVER	INGLEWOOD	CENTINELA	LINCOLN	PACIFIC
Location	Washington Blvd. (at creek)	Duquesne Ave. (at creek)	Duquesne Ave (at confluence)	Culver Blvd. (at Sepulveda Channel)	Inglewood Blvd. (at creek)	South of Centinela Ave. (McConnell Ave. at creek)	South of Centinela Ave. (at confluence)	Pacific Ave (at creek)
Historical ID & Agency	N/A	N/A	TS09 (LACDPW) Duquesne (S&T)	TS08 (LACDPW) Culver (S&T)	Inglewood (S&T)	N/A	N/A	Pacific (S&T)
Creek Section	Reach 1	Reach 2 (upper; at creek)	Reach 2 (confluence)	Sepulveda Channel	Reach 2 (lower; at creek)	Estuary (upper; at creek)	Estuary (confluence)	Estuary (lower; at creek)
Sampling Frequency	Weekly	Weekly	Weekly	Weekly	Weekly	Weekly	Weekly	Weekly

Figure 3.1 BC Bacteria
TMDL Monitoring Locations

3.2 Monitoring Locations

In accordance with the TMDL requirements, the responsible agencies propose to conduct weekly monitoring at eight (8) locations identified in **Table 3.1**. More details, including drainage maps, locations, and latitude and longitude coordinates of each site are available in *Appendix B*. A brief description of each monitoring location is as follows.

Site Id: BCB – 1	**Status:** New	**Location:** Ballona Creek Reach 1
Historical Site Id: N/A		
Comments: This is a new sample site located at *Washington Blvd*. The location is slightly downstream of the historical site TS10 (LACDPW) at La Cienega Blvd. Refer to Thomas Guide coordinates 633:A7		

Site Id: BCB – 2	**Status:** New	**Location:** Ballona Creek Reach 2
Historical Site Id: N/A		
Comments: This is a new sample site located at *Duquesne Avenue,* along the main channel of Ballona Creek and slightly upstream of the *Benedict Canyon Channel* confluence. Refer to Thomas Guide coordinates 672:H1		

Site Id: BCB – 3	**Status:** Existing	**Location:** Benedict Canyon Confluence
Historical Site Id: TS09 (LACDPW); Duquesne (S&T)		
Comments: This is an existing sampling site, located at the confluence of Ballona Creek and *Benedict Canyon*. The location is currently monitored by the City of Los Angeles as part of its S&T Program and was part of Los Angeles County's Core Monitoring Program under LA County Municipal Stormwater Permit. This site is the same as site BC-5 in Ballona Creek Metals and Estuary Toxics TMDL CMP. Refer to Thomas Guide coordinates 672:H2		

Site Id: BCB – 4	**Status:** Existing	**Location:** Sepulveda Channel
Historical Site Id: TS08 (LACDPW); Culver (S&T)		
Comments: This is an existing sampling site, located near *Culver Blvd*. The location is currently monitored by the City of Los Angeles as part of its Status and Trends Monitoring Program (Culver). This site is the same as site BC-4 in Ballona Creek Metals and Estuary Toxics TMDL CMP. Refer to Thomas Guide coordinates 672:E4		

Site Id: BCB – 5	**Status:** Existing	**Location:** Ballona Creek Reach 2
Historical Site Id: Inglewood (S&T)		
Comments: This is an existing sampling site currently monitored by the City of Los Angeles as part of its Status and Trends Monitoring Program. The site is located at *Inglewood Blvd.* on the main channel of Ballona Creek. Refer to Thomas Guide coordinates 672:E6		

Site Id: BCB – 6	**Status:** New	**Location:** Ballona Creek Estuary
Historical Site Id: N/A		
Comments: This is a new sample site located upstream of the Centinela Creek confluence at *McConnell Ave.* with the closest major street being South *Centinela Avenue.* Refer to Thomas Guide coordinates 672:D7		

Site Id: BCB – 7	**Status:** New	**Location:** Centinela Creek Confluence
Historical Site Id: N/A		
Comments: This is a new sampling site located at the confluence of Centinela Creek and Ballona Creek. The nearest major cross street is *Lincoln Avenue.* Refer to Thomas Guide coordinates 672:D7		

Site Id: BCB – 8	**Status:** Existing	**Location:** Ballona Creek Estuary
Historical Site Id: Pacific (S&T)		
Comments: This is an existing sampling site currently monitored by the City of Los Angeles as part of its Status & Trends Monitoring Program. The site is located at *Pacific Ave.* in the lower estuary. This is also an observation station for the Santa Monica Bay Beaches Bacteria TMDL. Refer to Thomas Guide coordinates 702:A2		

4.0 MATERIALS AND METHODS

This section provides a methodology for conducting field sampling at monitoring locations. Also discussed are procedures for bacterial analyses of the samples and data reporting procedures.

4.1 Sampling Schedule

During the ambient monitoring period the eight (8) proposed monitoring locations will be monitored weekly with samples to be collected on Mondays. When effectiveness monitoring begins, if there are exceedances in the weekly sampling during summer and winter dry weather, accelerated monitoring will be conducted. Accelerated samples will be collected 48 hours after the original bacterial exceedance and, if the 48-hour sample also exceeds, 96 hours after the initial bacterial exceedances. Sample collection and analysis for the proposed monitoring program will be done by the City of Los Angeles Watershed Protection Division (WPD) and Environmental Monitoring Division (EMD) respectively.

4.2 Sampling Procedures

The objective of the sampling program is to provide representative water samples for bacterial analyses, while following defined safety and quality assurance guidelines. The quality assurance guidelines shall include sampling protocol as well as sample documentation, preservation, and holding time requirements. All contracted samplers or agencies (City of Los Angeles) shall submit a Sample Collection Standard Operating Procedure (SOP) which should include sampling protocol and quality assurance guidelines. *Appendices C, D, and L* provide SOPs for review by the Regional Board

Each sampling event shall be associated with recorded observations of site conditions, which should minimally include sample ID, collection date and time, rain measurement (USC rain gauge), weather conditions, sample characteristics (water color and turbidity), and sampler's name (refer to *Appendix E*).

Sampling should only occur when conditions can be assessed as SAFE. The safety of the sample collector is the top priority and should supersede scheduled sampling.

4.2.1 Procedures for missed samples

For missed samples due to inaccessibility, when sample integrity is compromised, or the scheduled sampling day falls on a holiday, the site should be revisited and sampled on the earliest convenient day, except Sunday, within the week of the originally scheduled sampling date.

4.2.2 Procedures during Rainfall Events

During any rain event, field staff must use his/her best judgment to determine if sampling can be performed safely. If a sampling day happens to fall within the 24 hours following a rain event resulting in greater than 0.5" of precipitation, the safety of the sample collector is paramount and sampling may need to be rescheduled to a different time and/or day.

4.2.3 Procedures following Elevated Bacterial Levels (Exceedances)

During effectiveness monitoring, the City of Los Angeles (WPD and EMD) will conduct accelerated sampling and testing 48 hours after the initial bacterial exceedances and, if necessary, additional accelerated testing at 96 hours for those sites that still exceed the single sample limits after 48 hours. The purpose of the accelerated monitoring is to identify the persistence of an exceedance, especially during dry weather when source identification is a priority. Accelerated monitoring may not be as critical during wet weather at every location when the source of the exceedance is known to be stormwater runoff, therefore, accelerated testing during wet weather will be considered after the 4 year the re-opener.

4.2.4 Equipment

Equipment and supplies needed for sample collection are listed in *Appendix C*.

4.2.5 Safety

In an effort to improve employee safety and health awareness, and to prevent occupational related injury and illness, EMD and other participating laboratories have developed a safety program with the intention of satisfying the applicable federal, state, and local regulations. For example, EMD's Safety and Health Program is composed of specific elements required by Cal/OSHA General Industry Safety Order Section 5191:

Occupational Exposure to Hazardous Chemicals in Laboratories, and section 3203: The Injury and Illness Prevention Program, and any other applicable regulations. The written safety plan, titled ***The Chemical Hygiene Plan***, is available to all employees for review, and should be recognized as management's commitment to ensure that all employees carry out their work in the safest and most efficient manner possible. EMD employees will be kept familiar with the Division's written Chemical Hygiene Plan (CHP) through training, annual review and monthly staff safety meetings.

It is the City of Los Angeles' policy and the policy of other participating agencies to provide a safe working environment for all of their employees. In addition, all field and laboratory work is to be performed in a manner that provides the highest level of safety for the protection of every employee. See *Appendix L* for detailed safety protocols.

4.3 Analytical Methodology

Marine/brackish samples collected from the Estuary will be tested for the presence of total coliform, *E. coli*, and enterococcus bacteria. Freshwater samples will be tested for the presence of *E. coli* and fecal coliform in REC-1 and LREC-1 designated areas and for fecal coliform in REC-2 designated areas. All indicator groups will be quantified from a single sample collected at the designated monitoring site. Necessary dilutions or aliquot volumes shall be processed to ensure that compliance with water quality objectives can be determined. Bacterial results will be reported as the number of organisms per 100 mL of sample for each bacterial indicator. When selecting analytical bacterial methods for TMDL monitoring, the importance of fast recovery times (24 hours or less) should be emphasized. The presence of total coliform, *E. coli*, and enterococcus bacteria shall be detected and quantified using the defined chromogenic substrate (CS) method (SM 9223B, APHA 1992-98). Fecal coliforms shall be detected and quantified using the membrane filtration (MF) method (SM9221C APHA 1992-98).

For the marine/brackish samples (Ballona Estuary), the CS method will be used to convert the *E. coli* results to fecal coliform using a 1:1 translator. The application of a 1:1 translator was approved by the Regional Board in October 2002 after review of the Chromogenic Substrate and Membrane Filtration Comparison Study conducted by the City of Los Angeles (approval letter dated October 16, 2002, from Dennis Dickerson, Executive Officer).

The Responsible Agencies may consider conducting a fresh water study to draw conclusions about the relationship between *E. coli* and fecal coliforms similar to the above mentioned study conducted in Santa Monica Bay which led to the development of the 1:1 translator for *E. coli* to fecal coliforms in marine waters. Based on the execution and results of this future study, reporting of fecal coliform densities obtained and quantified by the MF method may be re-evaluated.

All laboratories performing analyses for TMDL bacterial monitoring shall maintain Environmental Laboratory Accreditation Program certification (ELAP administered by

California Department of Health Services) for specified methods from ELAP's "Field of Testing 126: Microbiology of Recreational Water". Additionally, all laboratories shall submit detailed SOPs for review by Regional Board staff. *Appendix G* provides an example of an SOP developed by the City of Los Angeles-EMD. Each analytical method used for the TMDL monitoring program shall be an approved EPA or Standard Methods for the Examination of Water and Wastewater, 18th-20th edition (APHA 1992-98) method. Laboratories receiving Regional Board approval may use other analytical bacterial methods for marine recreational and TMDL monitoring.

4.3.1 Quality Assurance/Quality Control

All laboratories must employ a program that associates quality assurance with the laboratory facility, staff, instrumentation and equipment, materials and methods, media and reagents, and data validation. These QA/QC measures may be included in the submitted SOPs or defined in a separate QA/QC document such as *Appendix I*. The quality assurance procedures shall be in accordance with Standard Methods for the Examination of Water and Wastewater, 18-20th Editions (APHA 1992-98). All participating laboratories must maintain ELAP certification, provide QA/QC documentation as required by the Regional Board, and participate in periodic inter-calibration exercises.

Data from the EMD Microbiology Laboratory will be utilized to comply with the monitoring requirements of the Ballona Creek Bacterial TMDL. The EMD and WPD divisions of the City of Los Angeles Departments will participate in this monitoring program as processing and sampling agencies respectively.

4.4 Data Management and Reporting

4.4.1 Data Tabulation

Results will be entered into Excel spreadsheets that automatically compute results (MPN/100 mL for CS analysis and CFU/100 mL for MF analysis). All entered data will be given secondary review, corrected as needed, to ensure error-free data entry. Examples of EMD's Microbiology Laboratory data worksheets can be found in *Appendix E*. Data acquisition, validation, reduction, and reporting procedures can be found in *Appendix H*.

4.4.2 Data Format and Archive

All data collected will be archived within the City of Los Angeles' Environmental Monitoring Division (EMD) Laboratory Information Management System (LIMS) database or comparable database. For any non-City of Los Angeles monitoring agency performing bacteriological analyses, data will need to be submitted daily to EMD

electronically in a comma-separated value (CSV) format that contains the table structure and syntax provided in *Appendix J*. The City of Los Angeles' Information & Control System Division (ICSD) staff will ensure electronic submissions of data are parsed and stored correctly into the LIMS database.

4.4.3 "Wet Weather" Determination

The BC Bacteria TMDL defines "wet weather" as "days with 0.1 inch of rain or greater and the three days following the rain event" (Attachment A to Resolution No. 2006-011, Page 4); however, the TMDL does not specify where the 0.1-inch of rain is to be measured. For clarification, the Ballona Creek Monitoring Sub-committee proposes in **Table 4.1** the rainfall gage to be used for this monitoring program to determine wet weather days.

Table 4.1 Rainfall gage to be used for the proposed monitoring program.

Jurisdictional Group	Rainfall Gage	Comment
Ballona Creek Watershed	University of Southern California (USC) (375)	LACDPW "Manually Observed Non-Mechanical Rain Gauge" Station

The proposed gage is a Manually Observed Non-Mechanical Rain Gauge station owned and operated by the County of Los Angeles. Data can be obtained at http://www.ladpw.org/wrd/precip/ under "Station Information." The web page displays 148 Manually Observed Non-Mechanical Rain Gages; these gages are measured once daily by volunteers and reported monthly.

4.4.4 Exceedance Determination and Accelerated Sampling

Bacteriological data will be summarized in tabular form on a daily basis by EMD's Microbiology Unit. Exceedances will be clearly notated and triggers indicating "accelerated monitoring needed" will be programmed into the report. Summer dry-weather, winter dry and wet weather spreadsheets with triggers will be created, but as mentioned in section 4.2.3 wet weather accelerated sampling will not be considered until the 4th year reopener. When bacterial levels no longer exceed listed standards, a trigger to return to weekly sampling will be programmed, except for wet weather exceedances which will continue regular sampling regardless of exceedances until the 4th year reopener.

The monitoring agency, the City of Los Angeles, will be responsible for performing accelerated monitoring as required. For the purpose of compliance, this CMP proposes that for single-sample limits, accelerated sampling results should not be counted towards compliance

4.4.5 Data Reporting

Electronically-formatted data will be archived and submitted to the responsible agencies and the Regional Board promptly after the data becomes available, and electronic copies of the monthly reports will be distributed to the responsible agencies. Monthly data summary reports will be submitted to the LARWQCB by the last day of each month for data collected during the previous month.

For EMD, laboratory results will be entered into Microsoft Excel spreadsheets that automatically compute results (MPN/100 mL or CFU/100 mL). All monitoring agencies will archive their own data within LIMS or a comparable database. See *Appendix H*, Data Acquisition, Reduction, Validation, and Reporting Procedures.

5.0 REFERENCES

American Public Health Association. 1992. Standard methods for the Examination of Water and Wastewater, 18th ed. American Public Health Association, Washington, DC, pp. 9-1 to 9-115.

Noble, R. T., J. H. Dorsey, M. K. Leecaster, M. Mazur, C. D. McGee, D. Moore, V. Orozco-Borbón, D. Reid, K. Schiff, P. M. Vainik, and S. B. Weisberg. 1999. Southern California Bight 1998 Regional Monitoring Program. I. Summer Shoreline Microbiology. Appendix C, Comparison of Bacterial Indicator Measurements among Southern California Marine Monitoring Laboratories. Southern California Coastal Water Research Project. Westminster, CA, 54-67.

TMDL Draft. The following TMDL drafts are cited in this report:

Total Maximum Daily Load to Reduce Bacterial Indicator Densities during Dry Weather at Santa Monica Bay Beaches—January 14, 2002

Santa Monica Bay Beaches Wet-weather Bacteria TMDL Draft—Version 4. 11/07/02.

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APPENDIX

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APPENDIX A

Development History of the Ballona Creek Bacteria TMDL

The Ballona Creek Bacteria TMDL was developed by the Los Angeles Regional Water Quality Control Board (RWQCB) to protect beneficial uses associated with water quality in Ballona Creek. Elevated concentrations of bacteria at Ballona Creek have prompted the development of a TMDL. The effective date of the TMDL is April 27, 2007.

Ballona Creek is a ten-mile long channel that begins in Hancock Park and drains into the Pacific Ocean just south of Marina del Rey. The Ballona Creek Watershed totals about 130 square miles. Ballona Creek has 3 segments (or reaches) divided based on the physical characteristics and beneficial use designations: Reach 1 is REC-2, Reach 2 is Limited REC-1, and the Estuary is REC-1. These three segments and Sepulveda Channel are listed as impaired and require a TMDL.

This bacteria TMDL addresses the impaired bacterial water quality of the creek and sets waste load allocations (WLAs) or enforceable bacteria concentration limits in the creek. Affected agencies will be required to reduce the amount of bacteria flowing in Ballona Creek, the Estuary, and Sepulveda Channel.

The watershed is highly developed, consisting of residential, recreational/open space, commercial and industrial land uses. The watershed also includes all or parts of the Cities of Beverly Hills, Culver City, Inglewood, Santa Monica, West Hollywood, and unincorporated Los Angeles County.

The TMDL contains a 14-year compliance schedule to correspond with the Santa Monica Bay Beaches Bacteria TMDL schedule for meeting 100% compliance of waste load allocations (WLAs). The TMDL will be re-evaluated 4 years after the effective date for WLAs based on results of required special studies from year 1 to 3.

A comprehensive Coordinated Monitoring Plan is required 12 months after the TMDL effective date. Compliance monitoring or “Effectiveness Monitoring” is required for 8 locations along the creek.

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APPENDIX B

Monitoring Sites

Table B.1 Effectiveness monitoring sites

Reach	Station ID	Station Name	Water Body	Sampling Frequency	Coordinates		Thomas Guide	Description (including historical sites, if any)
					Latitude	Longitude		
1	BCB-1	WASHINGTON	Main Channel: Ballona Creek	Weekly	N34 º 01.938’	W118 º 22.521’	633:A7	At Washington Blvd. (slightly downstream of LACDPW- TS10 at La Cienega Blvd).
2	BCB-2	DUQUESNE	Main Channel: Ballona Creek	Weekly	N34º 1.036’	W118º 23.35’	672:H1	At Duquesne Blvd. on the main channel of Ballona Creek.
	BCB-3	BENEDICT CANYON	Confluence: Benedict Canyon/Ballona Creek	Weekly	N 34º 00.870’	W118º 23.464’	672:H2	At the confluence of Benedict Canyon Channel/Ballona Creek (cross street is Duquesne Avenue).
	BCB-4	CULVER	Tributary: Sepulveda Channel	Weekly	N33º 59.886’	W118º 24.923’	672:E4	Near Culver Blvd. (same as site BC-4 in Ballona Creek Metals and Estuary Toxics TMDL CMP).
	BCB-5	INGLEWOOD	Main Channel: Ballona Creek	Weekly	N33º 59.387’	W118º 24.704’	672:E6	At Inglewood Blvd. on the main channel of Ballona Creek.
Estuary	BCB-6	CENTINELA	Main Channel: Ballona Creek	Weekly	N33º 58.922’	W118º 25.376’	672:D7	At McConnell Ave. on the main channel of Ballona Creek
	BCB-7	LINCOLN	Confluence: Centinela Creek/Ballona Creek	Weekly	N 33º 58.711’	W118º 25.549’	672:D7	At the confluence of Centinela Creek/Ballona Creek (cross street is Lincoln Avenue).
	BCB-8	PACIFIC	Main Channel: Ballona Creek	Weekly	N33º 57.679	W118º 27.142’	702:A2	In Ballona Creek Estuary, from Pacific Avenue bridge.

Figure B.1 Effectiveness monitoring sites drainage areas

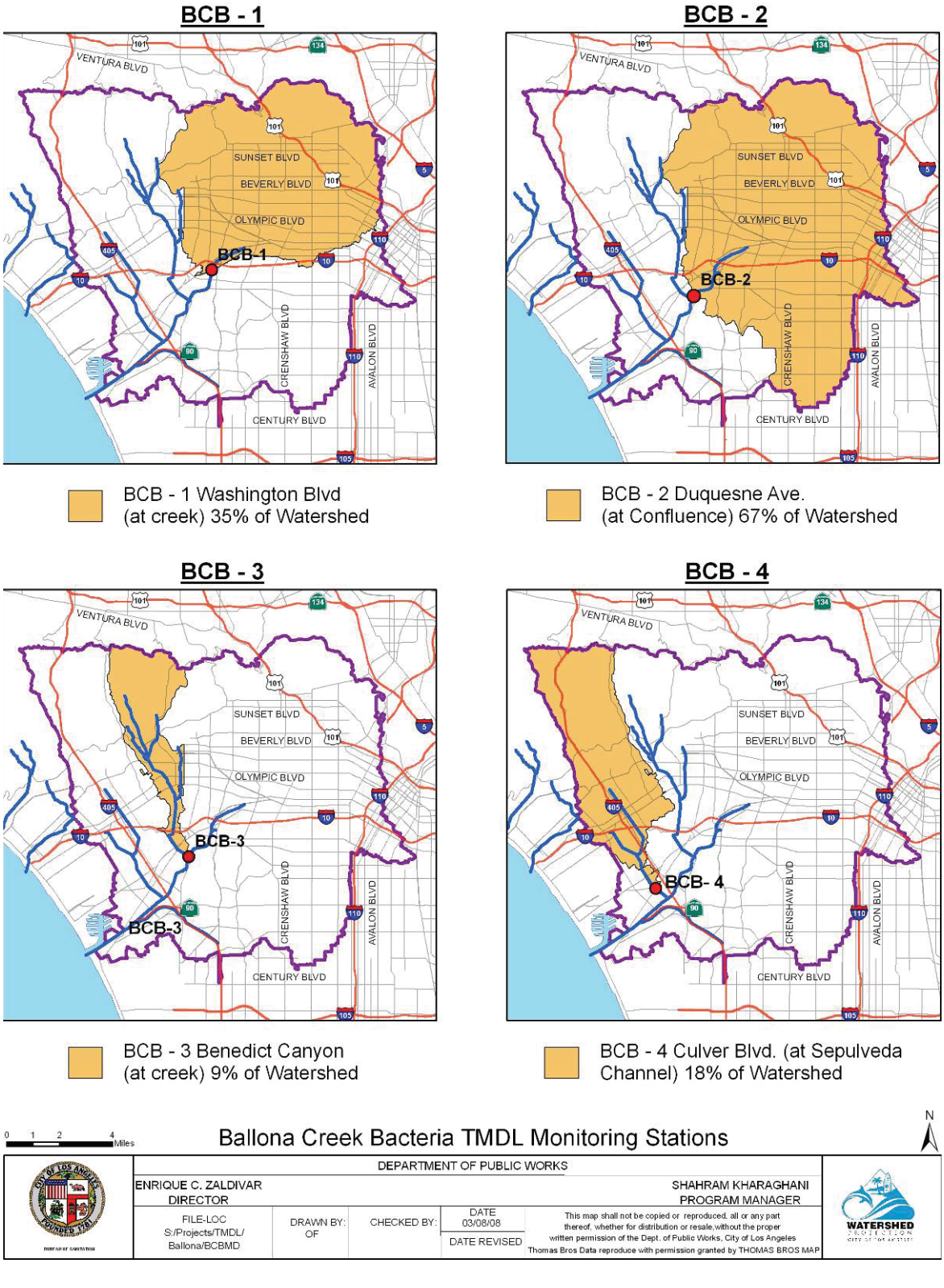
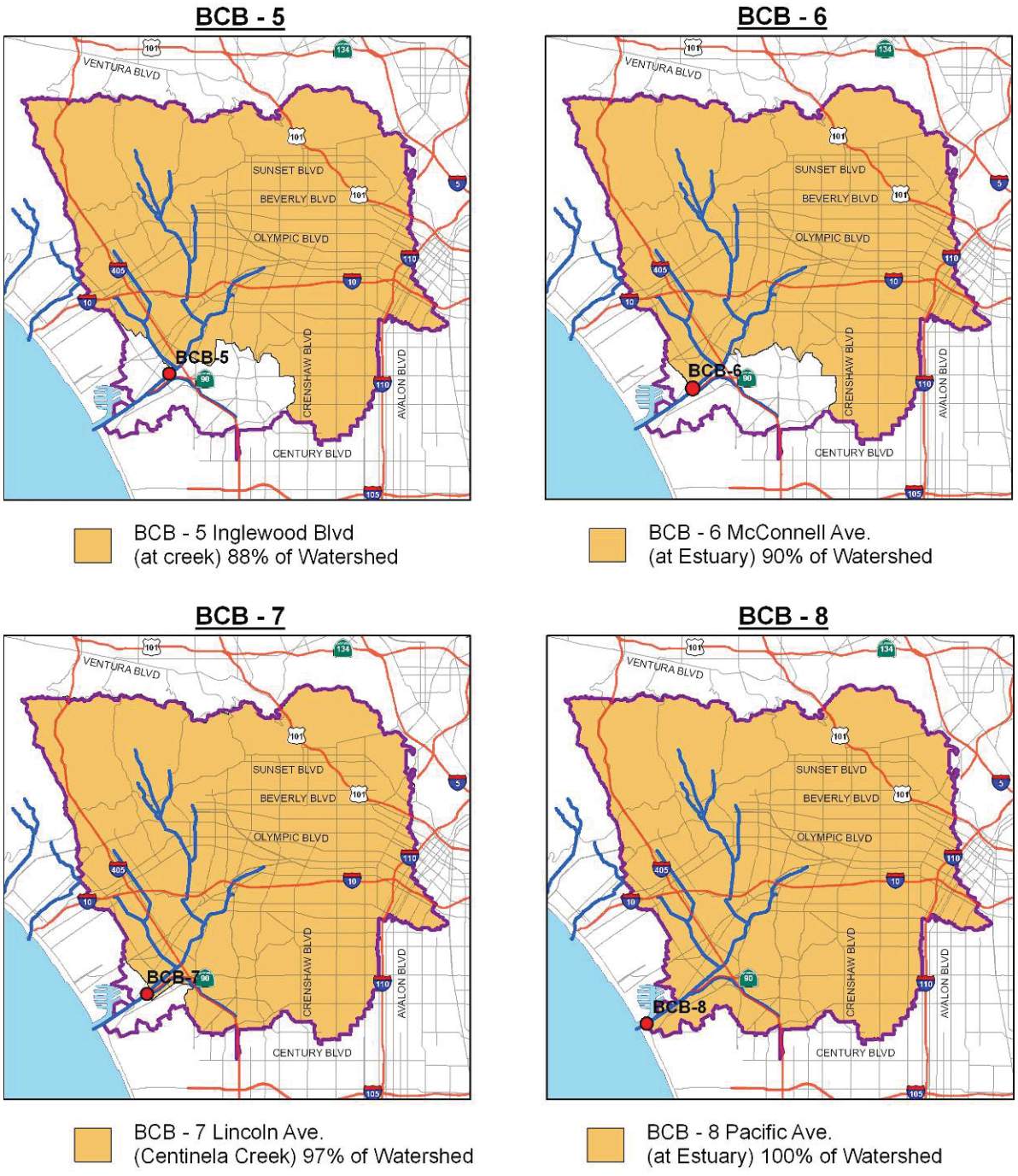


Figure B.2 Effectiveness monitoring sites drainage areas continued



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APPENDIX C

Field Sampling Equipment and Supply List

The following equipment is needed for dry weather water quality sample collection.

1. First Aid kit
2. Portable eyewash bottle with saline solution
3. Ice chest (with ice)
4. Sampling pole with reel
5. Weighted bottle holder (attaches to fishing line/reel)
6. Sterilized polypropylene 125 mL bottles with 1% Sodium Thiosulfate (necessary for freshwater/stormwater samples)
7. Wash bottle with de-ionized water
8. Foaming disinfectant hand cleanser
9. Waterproof labels
10. Paper towels
11. Water-safe pen and Lab marker
12. Field log sheet
13. Chain-of-Custody (COC) sheet
14. Thomas Guide (street map)/Electronic Navigation System
15. Trash bag
16. Cell phones (1 for each person)
17. Watch
18. Personal protective equipment:
    i. Safety vest (ANSI 107 Class 2 compliant, high visibility)
    ii. Protective gloves (latex, nitrile, etc.)
    iii. Slip-resistant shoes/boots
    iv. Protective eyewear: UV protection; impact resistant
    v. Foul weather gear (when necessary)
    vi. Rain boots (when necessary)
    vii. Life vest (if entering the flood channel).

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APPENDIX D

Field Sampling Standard Operating Procedures

I. Water Quality Sampling

A. Overview of Procedure

At the beginning of each month, Field Sampling staff provides Laboratory Staff at the Environmental Monitoring Division (EMD) with a sampling schedule detailing when sampling will be conducted, and the number of samples to be delivered. The Laboratory supplies Field Sampling staff with clean, sterile polypropylene bottles with the necessary additives. Sample bottles are labeled and Chain-of-Custody (COC) sheets are prepared prior to going out to the field. All necessary gear, including personal protective equipment, must be brought to the field. Grab samples are collected at designated sampling stations, and the time of collection is recorded on the COC and Field Log sheets. Samples are then stored on ice, sample temperature read and recorded by EMD laboratory staff at DSM (5^{th} floor, Pregerson Building, Hyperion Treatment Plant), and then delivered to the Microbiology Laboratory at the Environmental Monitoring Division (4^{th} floor, Pregerson Building, Hyperion Treatment Plant). Laboratory staff will need to make sure the samples are received within the maximum allowable holding time. The original COC sheet is signed, dated, noted as to the time samples are received and given to EMD staff. The Field Sampling crew retains a copy of the COC.

II. Sampling Procedure:

A. Coordination with Laboratory

At the beginning of each month, the monthly sampling schedule is sent via email to the supervisors of the Microbiology Section at EMD. If unforeseen changes are made to the schedule, EMD staff is notified immediately. Contact name is listed below:

Microbiology Section:

Water Microbiologist III

Supervisor: Ioannice Lee

Phone: (310) 648-5196

Email: Ioannice.Lee@lacity.org

B. Gather the necessary equipment:

See Appendix C

Sampling Locations/Frequency:

Reach	Station ID	Water Body	Sampling Frequency	Thomas Guide	Description (including historical sites, if any)
1	BCB-1	Washington Blvd.; Main Channel: Ballona Creek	Weekly	633:A7	At Washington Blvd. (slightly downstream of LACDPW-TS10 at La Cienega Blvd).
2	BCB-2	Duquesne Ave., Main Channel: Ballona Creek	Weekly	672:H1	At Duquesne Blvd. on the main channel of Ballona Creek.
	BCB-3	*Duquesne Ave., Confluence: Benedict Canyon/Ballona Creek	Weekly	672:H2	At the confluence of Benedict Canyon Channel/Ballona Creek (cross street is Duquesne Avenue).
	BCB-4	Culver Blvd.; Tributary: Sepulveda Channel	Weekly	672:E4	Near Culver Blvd. (same as site BC-4 in Ballona Creek Metals and Estuary Toxics TMDL CMP).
	BCB-5	Inglewood Blvd., Main Channel: Ballona Creek	Weekly	672:E6	At Inglewood Blvd. on the main channel of Ballona Creek.
Estuary	BCB-6	*Centinela Ave., Main Channel: Ballona Creek	Weekly	672:D7	At McConnell Ave. on the main channel of Ballona Creek
	BCB-7	*Lincoln Blvd., Confluence: Centinela Creek/Ballona Creek	Weekly	672:D7	At the confluence of Centinela Creek/Ballona Creek (cross street is Lincoln Avenue).
	BCB-8	Pacific Ave., Main Channel: Ballona Creek	Weekly	702:A2	In Ballona Creek Estuary, from Pacific Avenue bridge.

* Nearest major cross street to sample site. See provided GPS coordinate for actual sampling site.

C. Field Log sheet.
A field log sheet is provided in Appendix E. This form is for recording details about each sampling event (including date, time, locations, samplers, comments), and is retained by the sampling staff. The form is to be prepared before leaving to the field, and the appropriate information is filled out after each sample is collected.

D. Chain of Custody (COC) form.
A COC form is to be completed for each sampling event. The form should be prepared prior to leaving to the field. At each sampling station, the sampler enters his/her initials, along with time of collection. The original COC is to follow the samples at all times. The sampler must sign and date the COC when relinquishing the sample to Laboratory Staff (Sample Receiving, EMD) who in turn, signs the form to indicate receipt of the sample. A photocopy is given to the sampling staff, and the laboratory retains the original COC along with the samples to be analyzed. A blank COC is provided in Appendix E.

E. Collecting Samples
When sampling from a bridge, a fishing pole/reel is used to lower the sample bottle into the stream.
   a. Obtain clean and sterile polypropylene bottles with Sodium Thiosulfate (necessary for freshwater/stormwater samples). Confirm that the bottle has the appropriate pre-printed label.
   b. Note the sample collection time on the Field Log sheet, COC, and sample label.
   c. Be very careful to avoid contamination of the sample bottle. Wear clean gloves and avoid touching the mouth of the bottle and the inside of the cap.
   d. Attach the bottle-holder to the fishing line, and secure the bottle. Unscrew the bottle lid, and set it aside. Release the drag on the reel, and lower the bottle into the stream. Allow the bottle to fill with water, and then reel it in. Replace the lid securely, and place the sample into the ice chest.
   e. Rinse bottle holder with de-ionized water after each station.
   f. Fill in appropriate information on the COC and field log sheet.
   g. Samples should be delivered to the laboratory as soon as possible. When relinquishing custody of the samples, inform Laboratory staff of the start time of the six hour holding time limit for the samples. Laboratory staff will read the sample temperature, sign and date the COC, and make a copy of the COC for field staff to keep.
   h. Upon returning from the field, file the COC (copy) and field log sheet in the appropriate binder. Rinse all field equipment with de-ionized water.

III. Contact Information:

Laboratory:
Environmental Monitoring Division

Microbiology Section
Water Microbiologist III
Supervisor: Ioannice Lee
Phone: (323) 648-5196
Email: Ioannice.Lee@lacity.org

Watershed Protection Division

Pollution Assessment Section
Water Biologist III
Supervisor: Jon Ball
Phone: (323) 342-1557
Email: Jon.Ball@lacity.org

TMDL Implementation Section
Senior Engineer: Reza Iranpour, Ph.D., P.E.
Phone: (213) 485-0577
Email: Reza.Iranpour@lacity.org

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APPENDIX E

Field and Data Entry Worksheets

Examples of worksheets for Chain of Custody sheets (2 pages) and recording analytical results used by the City of Los Angeles' Watershed Protection Division and Environmental Monitoring Division are provided herein. They include field observations, Chromogenic Substrate data entry, and Membrane Filtration data entry. Once completed, data are then entered into the LIMS database.

CITY OF LOS ANGELES – DEPARTMENT OF PUBLIC WORKS – BUREAU OF SANITATION

WATERSHED PROTECTION DIVISION – SECTION

FIELD COLLECTION SHEET

Program:_____

Sampling Date: _____

STATIONS	STATION CODE	STAFF INITIALS	COLLECTION TIME	TEST REQUESTED	SAMPLE ID	COMMENTS (Weather, Water condition,…)

CHAIN-OF-CUSTODY

Relinquished by: (signature)	Print Name	Date/Time	Accepted by: (signature)	Print Name	Date/Time

Email results to:

REVISED DATE

Date:

Department of Public Works
Bureau of Sanitation
Environmental Monitoring Division

Sample Chain of Custody

EMD
LIMS #: _____

EMD Sample ID: _____
Project Name: _____

Sampling Information:
Sampling Agency: _____
Agency Sample ID#: _____
Phone Number: _____
Fax Number: _____
Contact Person: _____
email address: _____

Sampler's Name: _____
Sampler's Title _____

Sampler's Signature: _____

Witness: Name _____
Title _____

Name _____
Title _____

Sample Location: _____
_____

Sampling Program: _____
_____
_____
Purpose of program: _____
_____
_____
Report Time Frame: _____
_____
_____

Sample Date: _____

Sampling Time: _____

Sampling Address: _____
_____

Requested Analysis:
Metals: ☐
Organics: ☐
Conventional Chemistry: ☐
Micro Biological: ☐
Toxicity: ☐
Air Testing: ☐
See back of page for specifics analyses

Sample Notification:

PC: _____ Date: _____

Wet: _____ Date: _____

Micro: _____ Date: _____

Toxicity: _____ Date: _____

Metals: _____ Date: _____

Semi-Vol: _____ Date: _____

Volatile: _____ Date: _____

Current Holder Name	Signature	Title	Received Date	Received Time	Released Date

Analysis to be performed on the Sample(s):

EMD
LIMS #: _____

	Locator:	Collection Time:		Locator:	Collection Time:
-1			-6		
-2			-7		
-3			-8		
-4			-9		
-5			-10		

Sample Information: Liquid: ☐ Solid: ☐ Other: ☐ Temperature _____
Grab ☐ Composite: ☐
Start time: _____ Finish time: _____ pH _____
Container: Glass Size: _____ Color: _____ Number: ___
Plastic Size: _____ Color: _____ Number: ___ Residual Cl2 _____
Preservative ☐ Number of samples: ☐

Metals:

☐ Ag	☐ Cu	☐ Pb	☐ Other: _____	
☐ Al	☐ Fe	☐ Sb		
☐ As	☐ Hg	☐ Se		
☐ Ba	☐ K	☐ Sn		
☐ Be	☐ Mg	☐ Sr	☐ Total	
85 ☐ Ca	☐ Mn	☐ Tl	☐ Dissolved	
☐ Cd	☐ Mo	☐ V		
☐ Co	☐ Na	☐ Zn		
☐ Cr	☐ Ni			

Organics:

☐ VOC	☐ Pesticides/PCB	☐ Clopyralid	☐ Air VOC
☐ BNA	☐ Dioxin - screen	☐ Dioxin - low resolution	☐ Fixed Gases
☐ TOX	☐ Other: _____	☐ Dioxin - high resolution	☐ GC Sulfur
☐ Herbicides		☐ Tributyltin	☐ Siloxanes

Conventional Chemical:

☐ Alkalinity	☐ MBAS	☐ Solids:
☐ BOD	☐ Nitrogen:	☐ Total Solids
☐ Boron	☐ Ammonia Nitrogen	☐ Total Dissolved Solids
☐ Chloride	☐ Nitrate-N	☐ Total Suspended Solids
☐ COD	☐ Nitrite-N	☐ Settleable Solids
☐ Conductivity	☐ Organic-N	☐ Volatile Suspended Solids
☐ Cyanide (Free)	☐ Kjeldahl Nitrogen	☐ Volatile Total Solids
☐ Cyanide (Total)	☐ Oil & Grease	☐ Sulfates
☐ Flashpoint	☐ pH	☐ Sulfides, Total
☐ Fluoride	☐ Phenols	☐ Sulfides, Dissolved
☐ Grain Size	☐ Phosphate, Total	☐ Thiosulfate
☐ Hardness	☐ Phosphate, Dissolved	☐ TOC
☐ Hexavalent Chromium	☐ Radioactivity	☐ Turbidity
☐ H_2S	☐ Salinity	☐ Other:

Biological:

☐ Total Coliform	☐ Salmonella	☐ Other: _____
☐ Fecal Coliform	☐ Acute Toxicity (Fresh water)	
☐ E. coli	☐ Chronic Toxicity (Sea water)	
☐ Enterococcus	☐ Chronic Toxicity (Fresh water)	

Remarks: _____

Date:_____

Read by:_____ Time:_____

Environmental Monitoring Division

Microbiology Group

Validated:_____

QUANTITRAY COUNTS

TOTAL

Station	BCB-1	BCB-2	BCB-3	BCB-4	BCB-5	BCB-6	BCB-7	BCB-8	Blank	*Dup*
10 ml										
Large cells										
Small cells										
Blank 100 mL									Blank	
Large Cells										
Small Cells										

Station	BCB-1	BCB-2	BCB-3	BCB-4	BCB-5	BCB-6	BCB-7	BCB-8	Blank	*Dup*
10 ml										
Large cells										
Small cells										
Blank 100 mL									Blank	
Large Cells										
Small Cells										

Date: _____

ENVIRONMENTAL MONITORING DIVISION
Entered by 1: _____ 2: Validated by:_____
MICROBIOLOGY UNIT

BACTERIAL DENSITIES

ENTEROCOCCUS Read by: _____ Time: _____

VOL. (mL)	BCB-1	BCB-2	BCB-3	BCB-4	BCB-5	BCB-6	BCB-7	BCB-8	Blank	Dup
10										
50										
100										

E. coli ENTERO/100 mL

VOL. (mL)	BCB-1	BCB-2	BCB-3	BCB-4	BCB-5	BCB-6	BCB-7	BCB-8	Blank	Dup
10										
50										
100										

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APPENDIX F

Laboratory Equipment and Supply List

Chromogenic Substrate Method

- **Materials and Equipment**

  - Sterile, transparent, non-fluorescent container - 125 mL volume (use containers provided by Colilert kit if available)
  - Colilert-18 reagent packets
  - Enterolert reagent packets
  - Quantitray/2000 trays
  - Graduated cylinder, sterile - 100 mL (optional)
  - Quantitray/2000 rubber tray insert
  - UV cabinet or lamp - long wave, 366nm
  - Deionized water – sterile
  - Colilert Quantitray/2000 color/fluorescence comparators

Membrane Filtration Method

- **Materials and Equipment**

  - Plate Labeling
    - Indelible marking pen
    - Kimwipes
    - Prepared mEndo, mFC, and mE agar plates
    - Agar plate carrier with dark cover
  - Filtration
    - 1 mL and 10 mL sterile, bacteriological or Mohr disposable pipets
    - Pipet biohazard container
    - Vacuum pump
    - Filtration manifold
    - Microfil vacuum support base
    - Microfil filter screen disc (in 95% alcohol jar)
    - Sterile, disposable Microfil funnels
    - Membrane filters - sterile, white, grid-marked, 7mm diameter filters with 0.45µM pore size
    - Labeled mEndo, mFC, and mE agar plates in covered plate carrier
    - Alcohol lamp
    - 95% and 70% ethanol
    - Glass safety jar with lid
    - Paper towels
    - Sterile, plastic squirt bottle

- Forceps - smooth-tipped stainless steel
- Pipet bulb
- Alcohol pads
- Incubator, 35.0 ± 0.5°C
- Water bath, 44.5 ± 0.2°C
- Incubator, 41.0 ± 0.5°C
- Solid heat-sink fecal coliform incubator, 44.5 ± 0.2°C
- Matches
- Long-handled forceps
- Sterile, phosphate-buffered rinse water
- Sterile, phosphate-buffered water dilution tubes

o Colony Counting
- Binocular, stereoscopic microscope with fluorescent lamp
- Disposable gloves
- Data worksheets
- Large biohazard container
- Incubated mEndo, mFC, and mE agar plates
- EIA agar plates

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APPENDIX G

Laboratory Standard Operating Procedures (SOPs)

Chromogenic Substrate Method: Shoreline/Marine Samples

- **Procedure**
  - Disinfect the workbench area with 70% ethanol. Let air-dry.
  - Preparation of sample container
    - You will need one sterile container per sample. Label each sample container with station name and test to be performed (e.g., Container1: S01, TC/EC, Container 2: S01, Entero).
    - Remove the outer plastic ring/label seal around the container cap. Remove the container cap, being careful not to touch the inside of the cap. Pour sterile D.I. water from a flask into each container. Be careful not to touch the rim of the D.I. flask or the container. Pour the D.I. water to the 100 mL mark on each container and replace the cap. Replace the cap back onto the D.I. water flask if there is any D.I. water left in the flask.
    - If a 10-ml sample aliquot is to be used, remove 10 ml of D.I. water from all sample containers using a sterile 10 ml pipet. If only 1 ml of sample is to be analyzed, skip this step of removing 10 ml of D.I. water.
    - You will need one Coli-18 reagent pak for each sample container labeled TC/EC and one Enterolert reagent pak for each container labeled Entero. Carefully separate one reagent snap pak from the strip, taking care not to accidentally open the adjacent pak. Tap the snap pak to ensure that all of the reagent powder is in the bottom part of the pack.
    - Open the pak by snapping back the top at the scoreline. Do not touch the opening of the pak.
    - Add the reagents to the appropriate sample containers filled with D.I. water. Replace the cap on the container, tighten, and gently mix until the reagent is dissolved. Note that when the Coli-18 reagent is added to the D.I. water in the container, the solution is a clear color and when Enterolert reagent is added to the D.I. water, the solution is a yellow color.
    - Pipet 10 mL of each sample into the appropriate sample containers. Place the used pipets into the pipet biohazard container. Replace the sample container caps and mix gently.

  - Quanti-tray/2000
    - Turn on Quanti-tray® sealer at the start of sample preparation.
    - You will need **one** Quanti-tray for **each** labeled sample container.
    - Check to see that the green Ready Light (above the amber power light) is illuminated on the sealer. The sealer will not operate until

both the amber power light and the green Ready Light are illuminated.

- Using one hand, hold a Quanti-tray upright with the well side (plastic) facing your palm. Squeeze the upper part of the Quanti-tray so that it bends towards the palm of your hand. Using your other hand, gently pull the foil tab at the top of the tray to separate the foil from the top of the tray, creating an open pouch. Avoid touching the inside of the foil or tray and be careful not to tear the foil.
- Pour the reagent/sample mixture directly into the Quanti-tray, avoiding contact with the foil tab at the top of the tray. Tap the small wells at the bottom of the tray to release any air bubbles. Allow any foam present to settle.
- Place the sample-filled tray onto the rubber insert of the sealer with the well side (plastic) of the tray facing down. Align the small and large wells with their corresponding holes in the rubber insert. Make sure the tray is properly seated in the rubber insert. With your hand, gently press on the back of the tray to distribute some of the liquid into the larger wells.
- Slide the rubber insert into the sealer until the motor grabs the rubber insert and begins to draw it into the sealer.
- In approximately 15 seconds, the tray will be sealed and partially ejected from the rear of the sealer. Remove the rubber insert and tray from the rear of the sealer.
- If a misaligned tray is accidentally fed into the sealer, press and hold the "**reverse"** button (located on the top, front center of the sealer). This will reverse the motor and you can then remove the tray. Do not reverse the motor once the rubber insert has been drawn fully into the input slot of the sealer.
- Repeat for each labeled tray. Turn off the sealer and unplug the unit when you are finished sealing all the trays.
- Using a felt-tipped marker, label the front of each tray with the incubation time.
- Place all Quanti-trays labeled "TC/EC" into the 35°C (Total coliform) incubator for 18 hours.
- Place all Quanti-trays labeled "Entero" into the 41°C (Enterococcus) incubator for 24 hours.

o QA Controls
  - Refer to QA/QC SOP

o Clean-up
  - Dispose of the empty, used sample container in the large, red biohazard containers.
  - Dispose of all pipet wrappers and empty reagent packs in the regular trash receptacle. Return all lab supplies to their proper storage areas.

- Disinfect the workbench area with 70% ethanol. Let air-dry.
- Discard original sample remaining in sample bottle (can discard down sink drain). Rinse with tap water and place empty bottles on trash cart for later cleaning.

- Reading Quanti-Tray Sample Results
  - Disinfect the workbench area with 70% ethanol. Let air-dry.
  - TOTAL COLIFORMS - read 18-22 hours after incubation.
    - Remove the Quanti-trays from the 35°C (Total coliform) incubator.
    - Record the date, time, and analyst name or initials on the sample data sheet for the reading of Total Coliforms.
    - Compare the intensity of the yellow color of the sample wells to the intensity of the yellow color of the Comparator Quanti-tray. Any well with a yellow color of equal or greater intensity than the Comparator is considered a "positive" well. Wells with a clear color or a yellow intensity less than the Comparator are considered as "negative". **If reaction is unclear or borderline yellow, replace the tray in incubator for further incubation up to a total of 22 hours.**
    - Count the number of positive large wells. Remember that the single, large well at the very top of the Quanti-tray should also be included in the count if it is positive. Record the number of positive large wells on the sample data sheet. Count and record the number of large positive wells for each sample dilution that was set.
    - Count the number of positive small wells. Record the number of positive small wells on the sample data sheet. Count and record the number of small positive wells for each sample dilution that was set.

  - *E. coli*- read 18-22 hours after incubation.
    - These results are read from the Total coliform Quanti-trays.
    - Record the date, time, and analyst name or initials on the sample data sheet for the reading of *E. coli*.
    - Place Quanti-tray under a UV cabinet or lamp.
    - Press the red button on the top of the UV lamp to turn the lamp on. Make sure the lamp is pointed away from you.
    - Count the number of large and small fluorescent wells for each sample dilution. Remember that the single, large well at the very top of the Quanti-tray should also be included in the count for the large wells if it is positive. Record the results on the sample data sheet.
    - If in doubt as to the fluorescence of a well, compare it to the negative fluorescence of the Quanti-tray Comparator. This Comparator is "negative" for fluorescence. **If fluorescence on the well(s) is/are still questionable, mark the well(s) with an indelible pen or marker and re-incubate Quanti-tray for an additional 2 - 4 hours**. Read Quanti-tray again following the incubation period.

ENTEROCOCCUS - read 24-28 hours after incubation

- Remove the Quanti-trays from the 41°C (Enterococcus) incubator.
- Record the date, time, and analyst name or initials on the sample data sheet for the reading of Enterococcus.
- Place Quanti-tray under a UV cabinet or lamp
- Press the red button on the top of the UV lamp to turn the lamp on. Make sure the lamp is pointed away from you.
- Shine the UV lamp directly on the sample Quanti-tray within five inches of the tray. Count the number of large and small fluorescent wells for each sample dilution. Remember that the single, large well at the very top of the Quanti-tray should also be included in the count for the large wells if it is positive. Record the results on the sample data sheet.
- If in doubt as to the fluorescence of a well, compare it to the negative fluorescence of the Quanti-tray Comparator. This Comparator is "negative" for fluorescence. **If fluorescence on the well(s) is/are still questionable, mark the well(s) with an indelible pen or marker and re-incubate Quanti-tray for an additional 2 – 4 hours**. Read Quanti-tray again following the incubation period.

- When finished reading all the Quanti-trays, turn off UV lamp and dispose of all trays into the large red biohazard containers.
- Disinfect the work bench area with 70% ethanol. Let air dry.
- Leave the sample data sheets on the clipboard by the Quanti-tray sealer.

- Quanti-Tray Calculations
  - Enter the number of positive large and small wells into the Idexx generator or read from the Idexx MPN table. Multiply the number given in the table by the dilution factor used. If more than one dilution generates a result, take the average.

    Example # Positive large wells: 23

    # Positive small wells: 16

    Idexx MPN table: 52.7

    Calculation (10 ml aliquot of sample):

    52.7 (**number from table**) x 10 (**Result based on a 100 ml sample size**) = 530 MPN/100 ml

Membrane Filtration Method (for Enterococci analysis)

- **Media Preparation**
  - mEndo Agar LES

- To rehydrate the medium, suspend 51 grams in 1 liter deionized water containing 20 mL 95% ethanol and heat to boiling to dissolve completely. Cool to 45-50°C. (If using the agarmatic, follow the agarmatic directions for making mEndo.) Aseptically dispense 4-5 mL amounts into the lower halves of 60x15 mm sterile, disposable petri dishes and allow to solidify. Final pH 7.2 ± 0.2. Record pH results in the media prep log book.

- Set QA media controls.
  - Refer to QA/QC SOP
- Place agar plates in a labeled media container and refrigerate until needed. The holding time for agar plates is two weeks.

o mFC Agar

- To rehydrate the medium, suspend 52 grams in 1 liter deionized water and heat to boiling to dissolve completely. Add 10 mL of a 1% solution of rosolic acid in 0.2 *N* NaOH. Continue heating for 1 minute. Cool to 45 -50°C. (If using the agarmatic, follow the agarmatic directions for making mFC.) Aseptically dispense 4-5 mL amounts into the lower halves of 50-60x15 mm tight-fitting sterile, disposable petri dishes and allow to solidify. Final pH 7.4 ± 0.2. Record pH results in the media prep log book.

- 1% Rosolic Acid Solution - Add 0.1 grams rosolic acid to 10 mL of stock 0.2 *N* NaOH. Mix well.

- Stock 0.2 *N* NaOH - Add 0.8 grams NaOH to 100 mL deionized water. Mix to dissolve. Store in a labeled polyethylene reagent bottle.

- Set QA media controls.
  - Refer to QA/QC SOP
- Place agar plates in a labeled Tupperware container and refrigerate until needed. The holding time for agar plates is two weeks.

o mE Agar

- To rehydrate the medium, suspend 7.12 grams in 100 mL of deionized water. Heat to boiling to dissolve completely. Autoclave for 15 minutes at 121°C. Promptly remove from the autoclave and cool to 45-50°C. Add 0.024 grams Nalidixic Acid and 1.5 mL of a 1% solution of triphenyl tetrazolium chloride (TTC). (If using the agarmatic, follow the agarmatic directions for making mE.) Aseptically dispense 4-5 mL amounts into the lower halves of 60x15 mm sterile, disposable petri dishes and allow to solidify. Final pH 7.1 ± 0.2. Record pH results in the media prep log book.

  1% TTC Solution - Add 1 gram TTC to 100 mL of deionized water. Mix well. Using a sterile 0.22µm Millex-GS filter, filter-sterilize the

solution into a sterile, labeled 500 mL reagent bottle. Store in the refrigerator.

- Set QA media controls.
  - Refer to QA/QC SOP
- Place agar plates in a labeled Tupperware container and refrigerate until needed. The holding time for agar plates is two weeks.

o Esculin Iron Agar (EIA)
- To rehydrate the medium, suspend 1.65 grams in 100 mL of deionized water. Heat to boiling to dissolve completely. Autoclave for 15 minutes at 121°C. Promptly remove from the autoclave and cool to 45-50°C. (If using the agarmatic, follow the agarmatic directions for making EIA.) Aseptically dispense 4-5 mL amounts into the lower halves of 60x15 mm sterile, disposable petri dishes and allow to solidify. Final pH 7.1 ± 0.2. Record pH results in the media prep log book.
- Set QA media controls.
  - Refer to QA/QC SOP
- Place agar plates in a labeled Tupperware container and refrigerate until needed. The holding time for agar plates is two weeks.

o Phosphate-Buffered Water
- 1 *N* NaOH - Carefully add 4 grams NaOH to 100 mL deionized water. Mix to dissolve. Store in a labeled polyethylene reagent bottle.
- Stock Phosphate Buffer Solution - add 34.0 grams potassium dihydrogen phosphate (KH_2PO_4) to 500 mL deionized water and mix to dissolve. Adjust pH to 7.2 ± 0.5 with 1 *N* NaOH and bring volume to 1 liter, using a 1 liter volumetric flask. Transfer to a reagent bottle and autoclave for 15 minutes at 121°C. Let cool and refrigerate. Discard if turbidity is present.
- Stock Magnesium Chloride Solution - add 81.1 grams $MgCl_2 \cdot 6H_2O$ to 1 liter deionized water and mix to dissolve. Transfer to a reagent bottle and autoclave for 15 minutes at 121°C. Let cool and refrigerate. Discard if turbidity is present.
- Working Solution of Phosphate-Buffered Dilution/Rinse Water
  - Add 1.25 mL stock phosphate buffer solution and 5 mL stock magnesium chloride solution to 1 liter deionized water. Adjust pH to approximately 7.6-7.7 with 1 *N* NaOH. Mix and dispense approximately 9.5 mL into specially marked dilution test tubes. Autoclave at 121°C for 15 minutes. If phosphate-buffered rinse water is needed, autoclave 1-2 L volumes in large flasks for 45 minutes at 121°C.
  - Cool and check that buffered water level is at the marked line (9 mL) on the test tube. Aseptically adjust water level if necessary. Tightened test tube or flask caps and store at room temperature. Holding time for screw-capped media is

3 months. Final pH 7.2 ± 0.1.

- Sterility control - test the sterility of the buffered dilution water by aseptically pouring 2 test tubes of dilution water into a sterile bottle containing 100 mL of Tryptic Soy Broth. Test the sterility of the liter flasks of rinse water by aseptically adding 20 mL buffer to a sterile bottle containing 100 mL TSB. Incubate the bottle for 48 hours at 35.0 ± 0.5°C. Record pH and sterility check results in the media prep log book.

- Tryptic Soy Broth (TSB)
  - To rehydrate the medium, suspend 30 grams in 1 liter of deionized water and mix to dissolve completely. Dispense 100 mL of broth into 125 mL Nalgene bottles. Autoclave for 15 minutes at 121°C. Promptly remove from the autoclave when done. Let cool and then tighten caps. Final pH 7.3 ± 0.2. Record pH results in the media prep log book.
  - Set QA media controls.
    - Refer to QA/QC SOP
  - Place TSB bottles in the refrigerator until needed. The holding time for screw-capped media is three months.

- **Plate Labeling Procedure**
  - Clean and wipe the bench-top work area with 70% ethanol and let air dry.
  - Check the monthly sample calendar for the samples and duplicates scheduled for the day.
  - Check the QA results of the prepared agar plates to be used. These results are recorded in the media prep log book. Use only media that have passed the sterility, positive control, and negative control checks.
  - Record the media preparation dates for all the agar plates being labeled. The dates are recorded in the media prep log book under "Prep Date of Media in Use".
  - Inspect all agar plates.
    - Discard any plates that have bubbles that will interfere with bacterial growth when the membrane filter is placed on the agar surface.
    - Check plates for contamination of any kind (bacterial growth, mold, or strange color). Discard any contaminated plates into a biohazard bag.
  - Using an indelible marking pen or pre-printed labels, label each plate with the station name or location at the top of the petri dish, sample volume or dilution in the middle, and sample date at the bottom of the dish.
    - Consult the Sample Dilution Table for the necessary dilutions for each sample type.
    - mEndo and mFC agar plates are labeled on the bottom (agar side) of the petri dish.
    - mE agar plates are labeled on the top (lid side) and the bottom

(agar side) of the petri dish.

- Stack all the agar plates for the same station together after the plates are labeled. Stack plates by ascending volume order (smallest volume on top).
- When stacking, be sure to place all plates, agar side up.
- Place the stack of plates for each sample into a slot in one of the agar plate carriers.
- Add a small stack of unlabelled mEndo agar plates to the carrier. These plates will be used for QA blanks as needed during filtering.
- Label the cover of each plate carrier with the sample stations or locations for all plates in the carrier. Include duplicate stations on the label for all boat plate carriers.
- If plates are labeled one day in advance of use, refrigerate the plate carriers. Labeled plates that are refrigerated need to be taken out of the refrigerator on the day of use.
- If plates are labeled on the day of use, the plate carriers can be left out at room temperature until needed.

- **Filtration Procedure**
  - Clean and wipe the bench top work area with 70% ethanol and let air dry.
  - Gather the necessary filtration equipment.
  - Aseptically transfer sterile, phosphate-buffered rinse water into a sterile squirt bottle.
  - Select samples to be filtered. Select the proper agar plates for the samples and check the plate stacking order to make sure sample volumes are in ascending order.
  - Make 1:10 serial dilutions (if needed).
    - Shake the sample vigorously for several seconds (about 25 - 30 times) to break up any bacterial cell aggregates, to separate cells from particulate matter, and to make the sample homogenous.
    - Aseptically pipet 1 mL of the sample into a sterile 9 mL dilution test tube and shake or vortex vigorously. This is a 1:10 (10^{-1}) dilution of the sample.
    - Aseptically pipet 1 mL of the 10^{-1} dilution into a second 9 mL dilution tube and shake or vortex vigorously. This is a 1:100 (10^{-2}) dilution.
    - Aseptically pipet 1 mL from the second (10^{-2}) dilution tube into a third 9 mL dilution tube and shake or vortex vigorously. This is a 1:1000 (10^{-3}) dilution.
    - Continue making 1:10 serial dilutions as needed.
  - Fill the alcohol lamp with 95% ethanol and light it.
  - Prepare filtration equipment, one filtration unit per sample.
    - Wipe the Microfil support base with an alcohol pad. Let dry.
    - Remove filter screen disc from the 95% alcohol jar using the long-handled forceps. Gently shake the disc over the alcohol jar to remove any excess alcohol. Flame-sterilize the disc. Allow flame

to self-extinguish. Place disc onto the Microfil support base.
    - Squirt the disc with a small amount of sterile buffer to wash any residual alcohol off the disc. Apply vacuum to drain the buffer off the disc.
    - Aseptically remove a membrane filter from the filter dispenser, using an alcohol flame-sterilized forceps. Place the filter, grid-side-up on filter support base.
    - Aseptically remove a sterile, disposable Microfil funnel from the funnel dispenser.
    - Put the funnel over the filter on the support base. Place thumbs and index fingers of both hands on the upper, outside ridge of the funnel. Evenly push down on the funnel to securely lock it into place.
- Shake sample vigorously for several seconds (about 25 - 30 times) to break up any bacterial cell aggregates, to separate cells from particulate matter, and to make the sample homogenous. Place bottle at a slant to let any sand or debris in the sample settle to the bottom sides of the bottle.
- Record filtering start time and initials in the LIMS "Micro Log-in" Excel worksheet on the PC computer. Move the cursor to the appropriate cell for the sample being filtered.
    - If the starting time is the current time, press "CTRL+T".
    - Alternately, enter the time using a colon, ex. "10:25 or 14:00".
- Before filtering the sample, determine if a QA sterility blank needs to be done.
    - Refer to QA/QC SOP
- Wet the membrane filter with an adequate amount of sterile rinse water before adding sample aliquots delivered with a pipet. Add the sample aliquot to the filter according to the plate stacking order. Use a new filter for each sample aliquot.
- Use sterile pipets for sample volumes < 20 mL. If the pipet is to be used again, rest the pipet tip against the inner lip of the sample bottle. Do not let the pipet tip rest on the bottom of the sample bottle. Discard used pipets into the pipet biohazard container.
- For sample volumes of 50 mL or 100 mL, aseptically pour the sample to the measured lines on the Microfil funnel. If an excess amount of sample is poured into the funnel, use a sterile pipet to remove the excess. Discard the excess sample along with the pipet into the pipet biohazard container.
- Before applying the vacuum, swirl the sample in Microfil funnel by moving the funnel in a gentle circular motion to evenly distribute bacterial cells on the membrane filter surface.
- Apply vacuum, letting the sample drain through the filter.
- Thoroughly rinse down the walls of the funnel two times with a generous amount of sterile buffer water. This will wash down any bacteria that may adhere to the sides of the funnel.
- With one hand on the outside walls of the funnel, use a backwards and

upwards motion to pop the funnel off the support base. Continue to hold the funnel with your hand. Use your other hand to aseptically remove the filter with a flame-sterilized forceps (one sterile forceps per membrane filter). Aseptically replace the funnel back on the support base.

- Aseptically place the filter on the surface of the appropriate agar plate, using a rolling motion to avoid trapping air between the agar and the filter, which will result in the formation of bubbles. If any air is trapped under the filter, reset the membrane filter onto the agar surface. Place the used forceps into the jar of ethanol.
- Stack finished plates by sample and media type. Remember to always position finished plates agar (bottom) side up. This is to avoid any condensation dripping onto the surface of the filter during incubation, which may interfere with or distort bacterial growth.
- Continue filtering the sample, following the steps detailed above for each sample volume or dilution labeled on the stack of plates.
- If a duplicate sample is being filtered, the same pipets and dilution tubes (if needed) may be used for both the regular sample and the duplicate sample.
- When the sample is finished being filtered, place mEndo and mE agar plates in a covered incubation container (with moist sponges) according to media type. Total coliform mEndo agar plates are incubated for 23 ± 1 hour at 35.0 ± 0.5 °C. Fecal coliform mFC agar plates are incubated for 24 ± 2 hours at 44.5.0 ± 0.2 °C. It is important that fecal plates are incubated within 20 minutes of filtration to ensure heat-shock of the non-fecal bacteria. Plates are incubated in either the dry heat-sink incubators or sealed in water-proof bags and placed in the 44.5 ± 0.2°C water bath. Enterococcus mE agar plates are incubated for 48 ± 2 hours at 41.0 ± 0.5°C.
- Record filtration finish time, initials, and incubation time in the LIMS "Micro Log-in" Excel worksheet on the PC computer.
- The incubation containers should be labeled with the indicator bacteria, test date, and incubation time.
- Place used Microfil funnels in the biohazard bag for the funnels. Place sample bottles, empty buffer flasks, and used squirt bottles (if not being used for filtering more samples) in a tub for later washing.
- Wipe down the bench-top work area with 70% ethanol and let air dry.
- To filter another set of samples, wipe the Microfil support base and filter screen disc with a new alcohol pad. Rinse the disc with sterile rinse water. Repeat procedure as detailed in the above sections.
- When taking a long break between filtering samples, wipe the Microfil support base and filter screen disc with a new alcohol pad. Leave the alcohol pad on the screen disc. Place an alcohol-wiped cap over the Microfil unit. Before filtering again, remove the cap and re-wipe the Microfil unit and filter screen disc with the alcohol pad. Rinse the disc with sterile rinse water. Repeat procedure as detailed in the above sections.
- When all samples have been filtered, remove the filter screen disc from

the Microfil support base and put in the 95% alcohol jar. Wipe the Microfil support base with a new alcohol pad. Leave the alcohol pad in the empty disc space. Place an alcohol-wiped cap over the Microfil unit.

- **Colony Counting Procedure**
  - Check the LIMS "Micro Log-in" Excel worksheet for the incubation times of the plates that need to be read that day. Determine when the plates can be read according to their required incubation times.
  - Gather the necessary data worksheets for all samples to be read. Each test and sample type has separate data worksheets.
  - Record the time the plates are read and analyst initials in the LIMS "Micro Log-in" Excel worksheet and also on the data worksheets.
    - If the read time is the current time, press "CTRL+T".
    - Alternately, enter the time using a colon, ex. "10:25 or 14:00".
  - If desired, wear disposable gloves when handling and reading the plates.
  - Remove plates from the incubator when it is time to read them and arrange them in ascending volume order for each station.
  - Use the stereoscopic microscope with a fluorescent lamp to aid in identifying and counting colonies.
  - Starting with the control blank plate if one was done; examine the filter for bacterial contamination or any notable changes on the filter or agar media.
  - Examine and count all the plates set for a single sample, starting with the smallest sample volume filtered or the most dilute sample.
  - Colonies that have grown into each other should be counted individually. Separate nuclei or a fine line of contact may usually be seen.
  - Colonies in each and every filter grid square within the filtering area are to be counted.
  - To make counting easy and simple, start counting at the top of the filter. Count from left to right, following the grid lines, and continue to the bottom of the filter.
  - Countable ranges - Due to the possible adverse effect of colony crowding on sheen or color development on the filter membrane, and to be assured of a statistically valid colony count, minimum and maximum bacterial levels have been set for each of the indicator bacteria.
    - Total bacteria: <200 total colonies (background and indicator bacteria).
    - Total Coliform: 20 - 80 coliform colonies
    - Fecal Coliform: 20 - 60 fecal coliform colonies
    - Enterococcus: 20 - 60 enterococcus colonies
  - Colony Morphology
    - Total Coliforms
      - The typical colony has a pink to dark-red color with a shiny, greenish-gold, metallic surface sheen. The sheen may cover the entire colony, or it may appear only in the central area or on the periphery.
      - This sheen is produced as a by-product of lactose

fermentation (acid aldehyde complex) in combination with the Schiff's reagent (fuschin sulfite) in the mEndo media.

- Fecal Coliforms
  - Any colony exhibiting any light or dark blue color, whether covering the entire colony or only in or on part of the colony.
  - This blue color is a result of the acid produced by the fermentation of lactose combining with the aniline blue dye in the mFC media.
  - Colonies exhibiting a cream or grey color are not fecal coliforms.
- Enterococcus
  - After 48 ± 2 hours incubation, mE filters with growth on them are transferred to room temperature EIA plates.
  - Using forceps, remove the filter (handling the filter by its edge, outside of the filtration area) from the mE plate and roll it onto the agar surface of the EIA plate.
  - Replace the top of the EIA plate with the labeled top lid of the original mE plate.
  - Incubate the EIA plates for 20 minutes at 41.0 ± 0.5°C.
  - Enterococci are pink to carmine-red colonies with black or reddish-brown precipitate or halos on the underside of the filter when placed on EIA agar.
  - The colony color is due to the reduction of the vital indicator TTC (2,3,5-Triphenyl tetrazolium chloride) to non-reversible formazin. The dark precipitate or halo is the result of the hydrolysis of esculin.

- Record all colony counts and any other notable information on the data worksheet. Comments should include information about unusual conditions on the filter, such as the presence of solids, artifacts or high background counts. The condition of the growth on the filter should also be noted, such as confluent areas or confluent growth over the filter.
  - CG = confluent bacterial growth with indistinct or non-discrete colonies.
  - TNTC = Too Numerous To Count
  - >200 = greater than 200 background and indicator colonies on a filter.
- If there are any questions regarding counting colonies or any unusual or suspicious plates, save all plates for that sample and show them to a microbiologist.
- Dispose of all plates and gloves in a biohazard container. Autoclave at the end of the day.

- **Calculations**
  - Due to the possible adverse effect of colony crowding or color development on the filter membrane, and to be assured of a statistically valid colony count, minimum and maximum bacterial levels have been set

for each of the indicator bacteria.

- Total bacteria: <200 total colonies (background and indicator bacteria).
- Total Coliform: 20 - 80 coliform colonies
- Fecal Coliform: 20 - 60 fecal coliform colonies
- Enterococcus: 20 - 60 enterococcus colonies

o Indicator bacteria are expressed as bacterial density (CFU) per 100 mL of sample.

o The raw bacterial counts from the data worksheets are entered into LIMS "Sample Data Entry" Excel worksheets on the PC computer by a technician. The computer calculates the final bacterial densities for each sample and prints a copy of the data worksheet. See the LIMS Data Entry SOP for more details.

o The supervisor verifies the daily calculated bacterial densities. Daily bacterial density reports are printed out by the computer and E-mailed to the primary leads of the jurisdictional groups, who in turn will communicate this data to its jurisdictional members. The data reports are kept in a labeled notebook and the original data worksheets are kept in the data file cabinet. See the LIMS Data Validation SOP for more details.

o If the final bacterial densities need to be calculated by hand, the following guidelines should be used. All calculated values should have only 1 or 2 significant figures, depending on the colony counts.

- Countable Range (Std.Meth., EPA):

  Countable range number of colonies x 100 = (value) CFU/100 **mL filter volume**

Disregard non-countable range counts and volumes.

Volume	Count	
blank	0	
0.5	0	
5.0	6	$\frac{35}{20} \times 100 =$ **180 CFU/100 mL**
20	35	
50	95	

- Two volumes in the countable range (EPA):

  Calculate each count independently as in 6.4.1. above and then average the results.

Volume	Count		
blank	0	$\frac{20}{20} \times 100 = 100$	$\frac{60}{50} \times 100 = 120$
0.5	0		

5.0	6	
20	20	100 + 120 = **110 CFU/100 mL**
50	60	2

- Counts less than the countable range (Std. Meth.):

  Add all colonies x 100 = (value) CFU/100 mL
  Total all volumes

Volume	Count	
blank	0	
0.5	0	
5.0	1	19 + 4 + 1 + 0 x 100 = **32 CFU/100 mL**
20	4	50 + 20 + 5 + 0.5
50	19	

- No counts on any filter volume (EPA):

  1 x 100 = < (value) CFU/100 mL
  Largest vol filtered

Volume	Count	
blank	0	
0.5	0	1 x 100 = **<2 CFU/100 mL**
5.0	0	50
20	0	
50	0	

- Counts greater than the countable range - too numerous to count (TNTC) or confluent growth (CG) (EPA):

Highest upper limit count x 100 = >(value) CFU/ 100 mL
Smallest vol filtered

Volume	Count	For Total Coliforms:
blank	0	80 x 100 = **>16,000 CFU/100 mL**
0.5*	TNTC or CG	0.5
5.0	TNTC or CG	For Fecal Coliforms or Enterococci:
20	TNTC or CG	60 x 100 = **>12,000 CFU/100 mL**
50	TNTC or CG	0.5

*NOTE: If the count at the lowest dilution is TNTC, try to estimate the count on the plate. Estimate the count in a quadrant if necessary. Use this number to calculate the count per 100 mL.

- Confluent Growth Counts (Std. Meth., EPA):

  Disregard all dilution volumes that are confluent growth.
  Analyze remaining counts and volumes.

Volume	Count
blank	0
0.5	0
5.0	CG
20	CG
50	CG

$\frac{1}{0.5} \times 100 =$ **<200 CFU/100 mL**

Volume	Count
blank	0
0.5	3
5.0	20
20	CG
50	CG

$\frac{20}{5.0} \times 100 =$ **400 CFU/100 mL**

- Total bacterial count (background bacteria plus indicator bacteria) greater than 200 colonies (Std. Meth.):

  Analyze counts and volumes. Report as a greater than value.

Volume	Count
blank	0
0.5	0 (>200)
5.0	0 (>200)
20	CG
50	CG

$\frac{1}{5} \times 100 =$ **>20 CFU/100 mL**

Volume	Count
blank	0
0.5	0
5.0	3
20	18 (>200)
50	60 (>200)

$\frac{60}{50} \times 100 =$ **>120 CFU/100 mL**

- Total colonies less than 200, but indicator bacteria greater than upper limit (Std. Meth.):

  If plate has well isolated, discrete colonies that can be easily counted, use the higher count.

Volume	Count
blank	0
0.5	85
5.0	TNTC
20	TNTC
50	TNTC

$\frac{85}{0.5} \times 100 =$ **17,000 CFU/100 mL**

Volume	Count
blank	0
0.5	2
5.0	95
20	TNTC
50	CG

$\frac{95}{5} \times 100 =$ **1,900 CFU/100 mL**

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APPENDIX H

Data Acquisition, Reduction, Validation, and Reporting Standard Operating Procedure (SOP)

When performing analyses, results are generally tabulated onto laboratory worksheets (see Appendix E, Field and Laboratory Worksheets) but sometimes are generated electronically via instrumentation. Data on laboratory worksheets are entered into the Laboratory Information Management System using an Excel interface. These data are then validated through a quality assurance process that checks for correctness of data entry and validity of results. The analyst who generates the data has the initial and primary responsibility for the completeness and correctness of the data. The data are then checked by the unit supervisor (or designee). The following procedures describe the data acquisition and entry process then the quality assurance and quality control procedures.

Data Acquisition

Both raw and calculated data are acquired in the laboratory by manual, electronic, or direct computer acquisition. Acquired data are properly and securely stored for the duration specified by regulatory agencies or the customer. Guidelines for documentation and recording of information are as follows:

- Manual (Hand-written) Data Entry
    - Data are entered directly into the notebook or worksheet with non-erasable ink.
    - Data entries are signed and dated by the analyst making the entry. If the entry is more than one page, each page is signed and dated.
    - Mistakes are canceled by drawing a line through the entry, entering the correct value, and signing and dating the correction. The use of correction fluid is not acceptable.
    - Blank pages or substantial portions of pages with no entries are marked with a large "X" to indicate that they were intentionally left blank.

- Direct Computer Acquisition
    - In EMD's Microbiology Unit, the program/software used to generate results is prepared internally. A designated staff member of the Information & Control System Division (ICSD) at Hyperion has the responsibility of preparing the program and maintaining the supporting documents.
    - The laboratory relies on vendor-supplied information for the validity and integrity of instruments equipped with significant computer functions as an integral part of the system.

Data Reduction

Data reduction, where applicable, is described in specific SOP's. It involves reporting values with the appropriate significant figures in the concentration units established by the regulatory agency or the data user.

Procedure for Entering Microbiology Data into LIMS

- Log-On to LIMS Computer System
  - To log onto the LIMS system, double-click on the "Data Entry" icon on the PC computer screen.
  - A Microsoft Excel dialog box will appear. Select the "Enable Macros" button.
  - Wait until the "Microbiology Laboratory Worksheet StartDialog" dialog box appears.

- Data Entry for CS
  - Enter the sample date in the dialog box. Please note that current date is filled in by default.
  - Select the sample type. There is a list of sample locations to choose from. (E.g. 5-Mile, Ballona Creek, Cabrillo Beach, LAH Plume, SMB Plume Day1, Shoreline, Inshore, and so on.)
  - Dilutions for the CS method are not modified for rain events. For this method always make sure the "No" button is selected.
  - Select the "OK" button.
  - A computer form similar to the raw data worksheet will appear. Select the Excel worksheet tab for the type of test data to be entered. (ex. Total, *E. coli*, or Total & *E. coli*)
  - Enter analyst initials, date, and time into the computer in the designated cells.
  - Check to make sure the sample volumes or dilutions in the computer match the volumes or dilutions on the raw data worksheet. In the case of Ballona Creek, make changes to the volumes on the computer form, if necessary.
  - Enter the number of large and small positive wells.
  - Check to make sure all data has been entered correctly. If a calculated value does not appear for a sample, notify a microbiologist or the supervisor.
  - At the top of the computer worksheet, select the "Send Data to LIMS/Wisard" button.
  - Select the "Print" button at the top of the computer worksheet. A printed hardcopy of the raw data worksheet will print out on the printer in the micro lab.
  - Select the "New Worksheet" button at the top of the computer screen if entering data for another sample location. Select the "Save/Exit" button if all the data entry has been done.
  - If there are any problems or error messages regarding sending the data to LIMS, please contact LIMS staff at 55749 or 55120.

- Data Entry for MF
  - Enter the sample date in the dialog box. Please note that current date is filled in by default.
  - Select the sample type. There is a list of sample locations to choose from. (E.g. 5-Mile, Ballona Creek, Cabrillo Beach, LAH Plume, SMB Plume Day1, Shoreline, Inshore, and so on.)
  - If rain dilutions were used on the data worksheet, select "Yes" in the small "Rain" box. If normal dilutions were used, make sure the "No" button is selected.
  - Select the "OK" button.
  - A computer form similar to the raw data worksheet will appear. Select the Excel worksheet tab for the type of test data to be entered. (ex. Total, Fecal, Entero, or Total & Fecal)
  - Enter analyst initials, date, and time into the computer in the designated cells.
  - Check to make sure the sample volumes or dilutions in the computer match the volumes or dilutions on the raw data worksheet. In the case of Ballona Creek, make changes to the volumes on the computer form, if necessary.
  - Enter the bacterial colony counts.
  - Check to make sure all data has been entered correctly. If a calculated value does not appear for a sample, notify a microbiologist or the supervisor.
  - At the top of the computer worksheet, select the "Send Data to LIMS/Wisard" button.
  - Select the "Print" button at the top of the computer worksheet. A printed hardcopy of the raw data worksheet will print out on the printer in the micro lab.
  - Select the "New Worksheet" button at the top of the computer screen if entering data for another sample location. Select the "Save/Exit" button if all the data entry has been done.
  - If there are any problems or error messages regarding sending the data to LIMS, please contact LIMS staff at 55749 or 55120.

Review and Validation

Review

Data review is the process of comparing results to all available information, such as sample preparation and QC sample data, to evaluate the validity of the results. It supports the contention that the data are:

- Reasonable (experience with similar situations, common sense), and
- Capable of supporting a defensible decision.

The analyst and the unit supervisor (or designee) are responsible for reviewing the data relative to the following:

- Method blanks and QC sample
- Raw data
- Calculations
- Transcription

Validation

Data validation is the systematic procedure of reviewing data against a set of criteria to provide assurance of its validity before reporting the data. It is accomplished through routine examination of data collection, flow procedures, and QC sample results. It uses QC criteria to reject or accept specific data

- Validation includes the following:

    - Dated and signed entries by analysts on the worksheets and logbooks used for all samples.
    - Use of QC criteria to reject or accept specific data.
    - Checking of LIMS data entry and reporting

Validation Guidelines include the following:

    - Documentation of methods used and QC applied.
    - Maintenance performed on instruments.
    - Documentation of sample preservation, transport, and storage.
    - Review of QC sample data.

Data validation is performed, signed, and dated by the analyst, the unit supervisor (or designee), and where applicable, the laboratory manager.

Reporting

Data prepared for release to the Legal Reporting Unit are checked and approved by the unit supervisor (or designee) by the 5th of the following month for the previous month's data. The final report is prepared by the Legal Reporting Unit of EMD. The report is again scanned for missing data and outliers. Regulatory limitation calculations will be applied to the data set and exceedances clearly listed. If stations are out-of-compliance, accelerated monitoring will be indicated. Any regulatory required summary reports of source identification findings or sanitary surveys will be included. The report is signed by the Division Manager before distribution and may include the following:

- Sample ID used by the laboratory and the client (if available).
- Sample matrix type, description, and method number.
- The chemical/physical/biological parameters analyzed with the reported values and units of measurement.
- Data for all parameters reported with consistent number of significant figures.
- Results of QC samples, if appropriate.

- Footnotes referenced to specific data, if required, to explain reported values.
- If there are regulatory limits applicable to specific analyses, then limits are clearly notated and exceedances listed.
- Discussion on non-compliance data
- Report transmittal letter or memorandum identifying the person sending the report and the person(s) receiving the data.

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APPENDIX I

Quality Assurance/Quality Control (QA/QC)

The quality assurance objectives for measurement of data are unique to the particular program for which the data are collected and utilized. They describe the overall uncertainty that the data user is willing to accept in order to make decisions for environmental or other concerns. This uncertainty describes the data quality that is needed, which are usually expressed in terms of precision, bias, representativeness, comparability, and completeness.

The participating laboratories will use approved and recognized test methods, and comply with uncertainty requirements of the method. Quality control samples are measured and uncertainties are assessed and results must be within the range prescribed by the methods. Internal acceptance criteria are established by analyzing laboratory control samples on a daily basis. The participating laboratories will strive to meet the QA/QC goals described in this section and, therefore, be able to attest to the integrity of the sampling and analytical process.

The following QA/QC procedures will be conducted for sample collection, laboratory analyses, and data management to ensure the production of reliable and defensible data for Ballona Creek, estuary and tributaries.

Sample Collection

Only trained laboratory staff will be assigned to collect samples using proper sampling procedures, appropriate sampling equipment, required containers, and proper preservation techniques.

General guidelines for sample collection by laboratory staff are as follows:

- Assure sterility check on sample bottles and avoid contamination.
- Label sample containers with sample date, sample time, sampling point, sample type (grab/composite), preservatives added (if needed), the name of the sampler, and analyses needed.
- Use aseptic technique when collecting samples to prevent contamination (e.g. the inner surfaces or lip edges of the bottle or cap are not to be touched).
- Avoid collecting sample in multiple sweeps and no refilling of the sample bottle.
- Once the sample is collected, immerse at least one-third of the sample bottle in ice.
- Do not exceed maximum allowable transport time (time of sample collection to sample analysis) of 6 hours.
- Once received, log the samples into the laboratory system as soon as possible, assigned a unique login number, and properly stored.
- Sample preparation steps done prior to analysis, such as sample preservation are described in individual test SOP's.

Sample Handling

Chain-of-Custody

The purpose of the chain-of-custody is to establish detailed written and legal documentation of all transactions in which samples are transferred from the custody of one individual to another. The custody procedure is also used whenever samples are submitted to a laboratory within the division or to a contract laboratory. The chain-of-custody begins at the sample collection site and includes couriers or messengers who handle the sample in transit. It follows the sample in the laboratory until its ultimate disposal. It is a form of proof used to establish the authenticity and integrity of the sample, since the results will be used to show compliance with the TMDL requirements, i.e., numeric targets and waste load allocations.

A Chain-of-Custody (COC) must accompany each sample submitted to a participating laboratory. If a COC has not been filled out prior to delivery of the sample, a form will be provided to the delivery person prior to acceptance of said sample. The COC will be reviewed to make sure that all of the needed information has been supplied. As an example, the Chain-of-Custody Form being used at EMD is attached (Appendix E).

Samples that are collected by EMD's Microbiology Unit staff for bacteriological testing are delivered directly to the microbiology laboratory. A COC sheet is not required since technically there is no sample exchange, i.e., the sample collection staff and the analytical staff are one and the same.

Sample Holding & Preservation

Samples must meet EPA holding time requirements for each testing parameter. The sample refrigeration and holding time of six hours until analyses are performed are crucial for microbiological testing. Microbiological samples must be handled and stored under contamination free environments.

After the sample is received, the participating laboratory will enter the sample information into the Laboratory Information Management System (LIMS) or comparable database and a unique laboratory registration number will be generated for that sample.

Sample Disposal

After the analyses are completed, the sample will be retained as legal evidence or legally disposed of as determined by the microbiological analysis of the sample. Analyzed samples and standards used in analyses are disposed of in accordance with the laboratories written procedures, e.g., EMD's Chemical Hygiene Plan.

Analytical Procedures
Analyses

Analyses performed at EMD laboratories are generally driven by regulatory concerns and plant operations' requirements. There are many different analytical methods applicable to environmental analyses. EMD's methods are generally based on those specified by EPA, Federal and State regulatory agencies, or professional organizations. As a guide, references for the microbiological procedures are listed below.

"Standard Methods for the Examination of Water and Wastewater", 18th – 20thedition, 1992, 1998 respectively, APHA, AWWA, WPCF, Washington, DC.

"Microbiological Methods for Monitoring the Environment, Water, and Wastes", EPA-600/8-78-017.

Standard Operating Procedures (SOPs)

Routine analyses are defined in Standard Operating Procedures (SOPs), which are detailed descriptions of how to use and what to expect from a method. They contain method-specific QC criteria (i.e., instrument calibration, reagent blank, method blank, calibration standards, etc.), and QC requirements such as duplicate analysis, spike recoveries, holding time, etc. EMD follows a standardized SOP format, its content and application is presented in Appendix H of this document.

Microbiological Analyses

The following methods and target organisms are used in analysis of samples for Ballona Creek,estuary and tributaries:

- Membrane Filtration
  - Fecal coliform
- Chromogenic Substrate
  - Total coliform
  - *E. coli*
  - *Enterococcus*

For the BCB TMDL Monitoring Program, all methods used will be EPA, Regional Board, or Standard Methods for the Examination of Water and Wastewater (APHA, 18th-20th 1992, 1998, respectively) approved methods

The following QA/QC checklist is applicable for the chromogenic substrate and membrane filtration methods.

Chromogenic Substrate

- QC Checks on Idexx Reagent
    - Colilert-18 and Enterolert –sterility check performed with each use; autofluorescence, positive and negative controls; performed on each new lot of reagent
    - Monthly QC verification of at least 10 positive wells/target organism

- Quanti-trays:
    - Leak test performed on each new lot of trays

- DI Water
    - Sterility check performed with each autoclaved batch
    - Heterotrophic plate count performed monthly
    - Amm-N, Org-N, and TOC performed monthly
    - Heavy metals, total and single, performed annually
    - Total chlorine performed with each new batch
    - Water suitability test performed with change of E-Pure system filters or water source

- Equipment and Laboratory Environment:
    - Incubator temperatures checked twice daily (morning and late afternoon)
    - Refrigerator temperatures checked twice daily (morning and late afternoon)
    - Thermometers calibrated semiannually
    - Autoclaves calibrated semiannually; preventative maintenance performed quarterly
    - Air and Rodac testing for laboratory air and surface environments performed monthly.
    - Balances calibrated semiannually; weight check with each use
    - PH meters- calibrated semiannually; standardized with each use
    - Quanti-tray sealers checked and cleaned weekly

- Personnel QA checks
    - Reagent blanks
    - Sample duplicates (done on 10% of the samples per month)
    - Standard sample analysis and comparison count performed monthly

Membrane Filtration

- QC Checks on Media (mEndo, mFC, mE, EIA; phosphate buffered water):

    - mEndo, mFC, mE, EIA: pH, sterility check, and positive and negative controls with each new batch
    - Phosphate buffered water: pH and sterility check with each new batch
    - Monthly QC verification of at least 10 positive colonies/target organism

- Equipment and Laboratory Environment:
    - Incubator temperatures checked twice daily (morning and late afternoon)
    - Refrigerator temperatures checked twice daily (morning and late afternoon)
    - Thermometers calibrated semi-annually
    - Autoclaves calibrated semi-annually; preventative maintenance performed quarterly
    - Air and Rodac testing for laboratory air and surface environments performed monthly.
    - Balances calibrated semi-annually; weight check with each use
    - PH meters- calibrated semi-annually; standardized with each use
    - Residue on glass- performed annually for glassware and petri dishes
    - Water suitability test performed with change of E-Pure system filters or water source

- Personnel QA checks (performed by all technical lab staff)
    - Reagents blanks
    - Sample duplicates (done on 10% of the samples per month)
    - Standard sample analysis and comparison count performed monthly for MF analysis

System and Performance Audits

An audit is a periodic check to ensure that the laboratory operates according to the policies and procedures described in the Quality Assurance Manual, complies with good laboratory practices, and meets the requirements of regulatory agencies. It may be either a system or performance audit.

<u>System Audit</u>

A system audit is a review of laboratory operations conducted to verify that the laboratory has the necessary facilities, equipment, staff, and procedures in place to generate acceptable data. It is an on-site inspection of the laboratory's system of operations. It may be an internal or external audit. Internal inspections may be performed by quality assurance personnel. External audits are generally laboratory certification-related activities.

1. Internal

Periodically, the QA Officer (or designee) audits the laboratories and reports the results to the Division Manager (or laboratory director), laboratory managers, and unit supervisors.

2. External

State-certified laboratories are site visited every two years by auditors from the Environmental Laboratory Accreditation Program (ELAP) of the California Department of Health Services (CA DOHS). Accreditation is by scientific discipline or field of testing. Non-compliances with good laboratory practices are identified and reported as deficiencies and are subject to corrective action before accreditation is renewed.

Performance Audit

A performance audit is a review to evaluate the laboratory's analytical activities as well as the data produced by analysts. It verifies the ability of the laboratory to correctly identify and quantify compounds in unknown samples submitted by the auditing entity. The purpose of these audits is to determine the laboratory's capability to generate scientifically sound data.

1. Internal

Periodically, the QA staff submits unknown samples to most of the laboratories. These samples are usually from the inventory of previous Performance Evaluation (PE) samples from EPA. Analysis of these samples is also a corrective action requirement for Discharge Monitoring Report (DMR) and/or Water Pollution (WP) samples evaluated with "unacceptable results". The QA staff may also conduct intra- and inter-comparison studies.

2. External

All laboratory units, including the Microbiology laboratory, at EMD participate in mandatory QA Performance Evaluation (PE) Study Programs.

a. Mandatory PE Programs

* Water Pollution QA Study Program (WP) serves a dual purpose. It satisfies EPA's wastewater testing laboratory requirements and meets one of ELAP's laboratory certification criteria. Test samples are analyzed for parameters listed under each field of testing on our certifications and are specified in the WP Program following certified procedures. A laboratory can participate in a WP Study twice a year.

* For the Microbiology Performance Evaluation (PE) Study, Drinking Water/Wastewater Enumeration is required for ELAP certification. Like all the other PE programs, the samples are acquired from NIST-approved vendors and analyses are done for certified analytes.

b. Voluntary PE Program

The Microbiology Unit also takes part in the inter-laboratory calibration studies with EPA. These programs are performance based.

Assessment of Precision and Accuracy

Data quality may be assessed in terms of precision, accuracy, representativeness, completeness, and comparability. The latter three are usually determined outside of the laboratory operations and with limited involvement of laboratory staff. These measures are not included in this section. The internal quality control measures (i.e., precision and accuracy) that are performed in the laboratory to evaluate data quality are described in this section.

Precision

Precision is the agreement among a set of replicate measurements without knowledge of the true value. It is the degree to which a measurement is reproducible. Precision, expressed as Relative Percent Difference (RPD), is determined for each laboratory unit by analyzing replicates of the same sample, a number of duplicate pairs, or matrix-spiked duplicate samples.

Accuracy

Accuracy is a measurement of how close the result is to the true value. Each laboratory unit establishes its accuracy of measurement by analyzing QC check samples (spiked samples, standard reference materials from a reliable source, etc). The results of the QC samples are correlated to documented, certified values. Results of spiked samples are calculated as Percent Recovery. Actual Percent Recovery is compared to established reference data. The degree of closeness of the QC check sample contributes to the general assurance that the accuracy of the data is within acceptable limits.

Corrective Action

Laboratory events and data that fall outside established quality acceptance criteria may require investigation or corrective action. The corrective action implemented depends on the type of analysis, the extent of the error, and whether the error can be determined and

corrected. The purpose of the corrective action is to resolve the problem and to restore the system to proper operation. Investigative steps and corrective actions implemented are documented.

Corrective Action Procedures

1. The initial corrective action procedures may be handled at the bench level. The unit supervisor is immediately notified of the deviation. The analyst reviews the sample preparation for possible errors and checks the instrument calibration, calibration and spike solutions, instrument sensitivity, etc.

2. If the error cannot be resolved by the analyst, the unit supervisor has the responsibility of resolving the problem with assistance, if needed, from the laboratory manager and/or the QA Officer.

3. The corrective action adopted may be determined by the analyst, the unit supervisor, the laboratory manager, the QA Officer, or through a consensus. If needed, the final decision for corrective action rests with the laboratory manager after consultation with the QA Officer.

4. The unit supervisor shall maintain an accurate and up-to-date record of corrective actions taken in the unit. A corrective action report form (included herein as an attachment) is available for use.

5. The laboratory manager shall periodically review corrective action records and plan for system improvement by involving analysts, unit supervisors, and QA personnel.

General Guidelines for Initiating a Corrective Action

1. Identify/define the problem.
2. Assign responsibility for investigating the problem.
3. Investigate and determine the causes.
4. Develop corrective action to eliminate the problem.
5. Measure the effectiveness of the corrective action.
6. Analyst, unit supervisor, laboratory manager, and the QA Officer meet to review and evaluate the process, if necessary.
7. Document the process by filling out the Corrective Action Report Form.

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APPENDIX J

Data Format and Archive

Data format. List of fields, type of data, whether it is required, and description of data format to be used for submission for archival.

Field Name	*Type*	*Required*	*Description*
Agency	Text	Y	A unique code used by the submitting agency (luAgency)
Account	Text	Y	Place-holder code to contain “TMDL”.
Program	Text	Y	Place-holder code to contain “BC TMDL”.
StationID	Text	Y	The station name from the list of stations provided in lookup list (luStations).
AgencySampleID	Text	N	The laboratory internal sample identifier
SampleDate	Date/Time	Y	The date the sample was analyzed (must be the same date as when the sample was taken) expressed as dd-mmm-yyyy
SampleTime	Number	Y	The time the sample was collected expressed as hh:mm
SamplerID	Text	Y	Name of person collecting sample
AnalysisDate	Date/Time	Y	The date the sample was analyzed (must be the same date as when the sample was taken) expressed as dd-mmm-yyyy
AnalysisTime	Number	Y	The time the testing was started expressed as hh:mm
AnalystID	Text	Y	Name of person analyzing sample
ParameterCode	Text	Y	What type of bacteria are being tested
Qualifier	Text	N	Qualifier for the result
Result	Number	Y	The numerical results of the test
ResultUnits	Text	Y	The units for the results
TextValue	Text	Y	Explanation for sample not analyzed, default None, luAnalyticalFailure
Dilution	Number	Y	The dilution factor associated with the result.
LabRep	Text	Y	The count of the lab replicate.
AnalysisMethod	Text	Y	The Method used to do the analysis
Comments	Text	N	Additional comments

luAgencyCode	
Agency Code	**Agency Description**
CLA EMD	City of Los Angeles, Environmental Monitoring Division
DHS	Department of Health Services
LACSD	Los Angeles County Sanitation Districts

luStations	
Station Name	**DESCRIPTION**

luAnalyticalFailure	
None	No analytical failure, default value
AE	Analyst error
NA	Station not accessible, no sample taken
NS	No sample
NT	Sample not tested

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APPENDIX K

State of California
California Regional Water Quality Control Board, Los Angeles Region

RESOLUTION NO. 2006-011
June 8, 2006

Amendment to the Water Quality Control Plan for the Los Angeles Region to Incorporate a Total Maximum Daily Load for Bacteria in Ballona Creek, Ballona Estuary and Sepulveda Channel.

WHEREAS, the California Regional Water Quality Control Board, Los Angeles Region, finds that:

1. The Federal Clean Water Act (CWA) requires the California Regional Water Quality Control Board (Regional Board) to develop water quality objectives which are sufficient to protect beneficial uses for each water body found within its region.

2. A consent decree between the U.S. Environmental Protection Agency (USEPA), Heal the Bay, Inc. and BayKeeper, Inc. was approved on March 22, 1999. This court order directs the USEPA to complete Total Maximum Daily Loads (TMDLs) for all impaired waters within 13 years. A schedule was established in the consent decree for the completion of the first 29 TMDLs within 7 years. The remaining TMDLs will be scheduled by Regional Board staff within the 13-year period.

3. The elements of a TMDL are described in 40 CFR 130.2 and 130.7 and section 303(d) of the CWA, as well as in USEPA guidance documents (Report No. EPA/440/4-91/001). A TMDL is defined as the sum of the individual waste load allocations for point sources and load allocations for nonpoint sources and natural background (40 CFR 130.2). Regulations further stipulate that TMDLs must be set at levels necessary to attain and maintain the applicable narrative and numeric water quality standards with seasonal variations and a margin of safety that takes into account any lack of knowledge concerning the relationship between effluent limitations and water quality (40 CFR 130.7(c)(1)). The regulations in 40 CFR 130.7 also state that TMDLs shall take into account critical conditions for stream flow, loading and water quality parameters.

4. The numeric targets in this TMDL are not water quality objectives and do not create new bases for enforcement against dischargers apart from the water quality objectives they translate. The targets merely establish the bases through which load allocations (LAs) and waste load allocations (WLAs) are calculated. WLAs are only enforced for a discharger's own discharges, and then only in the context of it National Pollutant Discharge Elimination System (NPDES) permit, which must be consistent with the assumptions and requirements of the WLA. The Regional Board will develop permit requirements through a subsequent permit action that will allow all interested persons, including but not limited to municipal

storm water dischargers, to provide comments on how the WLA will be translated into permit requirements.

5. Upon establishment of TMDLs by the State or USEPA, the State is required to incorporate the TMDLs along with appropriate implementation measures into the State Water Quality Management Plan (40 CFR 130.6(c)(1), 130.7). This Water Quality Control Plan for the Los Angeles Region (Basin Plan), and applicable statewide plans, serve as the State Water Quality Management Plans governing the watersheds under the jurisdiction of the Regional Board.

6. As envisioned by Water Code section 13242, the TMDL contains a "description of surveillance to be undertaken to determine compliance with objectives." The Compliance Monitoring and Special Studies elements of the TMDL recognize that monitoring will be necessary to assess the on-going condition of the Ballona Creek, Estuary, and their tributaries and to assess the on-going effectiveness of efforts by dischargers to reduce bacteria loading to these waterbodies. Special studies may also be appropriate to provide further information about new data, new or alternative sources, and revised scientific assumptions. The TMDL does not establish the requirements for these monitoring programs or reports, although it does recognize the type of information that will be necessary to secure. The Regional Board's Executive Officer will issue orders to appropriate entities to develop and to submit monitoring programs and technical reports. The Executive Officer will determine the scope of these programs and reports, taking into account any legal requirements, and issue the orders to the appropriate entities.

7. Ballona Creek flows as an open channel for just under 10 miles from Los Angeles (South of Hancock Park) through Culver City, reaching the Pacific Ocean at Playa del Rey. It is entirely lined in concrete and is fed by a complex underground network of storm drains, which reaches north to Beverly Hills and West Hollywood. Tributaries of the creek include Centinela Creek, Sepulveda Canyon Channel, Benedict Canyon Channel, and numerous other storm drains. The creek meets Ballona Estuary, at Centinela Avenue, where concrete is replaced by grouted riprap side slopes and an earthen bottom. Ballona estuary flows into the Santa Monica Bay, and its water quality affects the adjacent shoreline of Dockweiler Beach.

8. The Regional Board's goal in establishing the Ballona Creek, Ballona Estuary, and Sepulveda Channel TMDL is to reduce the risk of illness associated with recreating in waters contaminated with human sewage and other sources of bacteria. Local and national epidemiological studies compel the conclusion that there is a causal relationship between adverse health effects, such as gastroenteritis, and recreational water quality, as measured by bacteria indicator densities.

9. The Regional Board recognizes that there are two broad approaches to implementing the TMDL. One approach is an integrated water resources approach. An integrated water resources approach has been previously defined by the Regional Board in the Santa Monica Bay Beaches Bacteria Wet Weather TMDL (Regional Board Resolution No. 2002-022 and attachments). For clarification, the Regional Board considers natural treatment systems (e.g. grassy swales, wetlands, vegetated buffers) to be consistent with an integrated water resources approach.

10. Regional Board staff have prepared a detailed technical document that analyzes and describes the specific necessity and rationale for the development of this TMDL. The technical

document entitled "Total Maximum Daily Loads for Bacterial Indicator Densities in Ballona Creek, Ballona Estuary, and Sepulveda Channel" is an integral part of this Regional Board action and was reviewed, considered, and accepted by the Regional Board before acting. Further, the technical document provides the detailed factual basis and analysis supporting the problem statement, numeric targets (interpretation of the numeric water quality objective, used to calculate the load allocations), source analysis, linkage analysis, waste load allocations (for point sources), load allocation (for nonpoint sources), margin of safety, and seasonal variations and critical conditions of this TMDL.

11. On June 8, 2006, prior to the Board's action on this resolution, public hearings were conducted on the "Total Maximum Daily Loads for Bacterial Indicator Densities in Ballona Creek, Ballona Estuary, and Sepulveda Channel". Notice of the hearing for the "Total Maximum Daily Loads for Bacteria Densities in Ballona Creek, Ballona Estuary, and Sepulveda Channel" was published in accordance with the requirements of Water Code section 13244. This notice was published in the Los Angeles Times on April 3, 2006.

12. The public has had reasonable opportunity to participate in review of the amendment to the Basin Plan. A draft of the TMDL for bacteria densities in Ballona Creek, Ballona Estuary, and Sepulveda Channel was released for public comment on April 3, 2006; a Notice of Hearing and Notice of Filing were published and circulated 45 days preceding Board action; Regional Board staff responded to oral and written comments received from the public; and the Regional Board held a public hearing on June 8, 2006 to consider adoption of the TMDL. In addition, input from participants in the stakeholder group "Cleaner Rivers through Effective Stakeholder TMDLs" (CREST) was solicited in developing potential implementation options to achieve compliance with the waste load allocations, and in estimating associated costs of selected strategies. CREST is a stakeholder effort initiated by the City of Los Angeles geared towards collaborative TMDL development in the Los Angeles River and Ballona Creek watersheds.

13. In amending the Basin Plan, the Regional Board considered the factors set forth in sections 13240 and 13242 of the Water Code.

14. The amendment is consistent with the State Antidegradation Policy (State Board Resolution No. 68-16), in that the changes to water quality objectives (i) consider maximum benefits to the people of the state, (ii) will not unreasonably affect present and anticipated beneficial use of waters, and (iii) will not result in water quality less than that prescribed in policies. Likewise, the amendment is consistent with the federal Antidegradation Policy (40 CFR 131.12).

15. Pursuant to Public Resources Code section 21080.5, the Resources Agency has approved the Regional Water Boards' basin planning process as a "certified regulatory program" that adequately satisfies the California Environmental Quality Act (CEQA) (Public Resources Code, Section 21000 et seq) requirements for preparing environmental documents. (14 Cal. Code Regs. § 15251(g); 23 Cal. Code Regs. § 3782.) As such, the Regional Water Board's basin planning documents together with an Environmental Checklist, are the "substitute documents" that contain the required environmental documentation under CEQA. (23 Cal Code Regs. § 3777.) The detailed technical report entitled "Total Maximum Daily Load for Bacteria Densities in Ballona Creek, Ballona Estuary, and Sepulveda Channel," responses prepared by staff to address comments raised during the development of the TMDL, this resolution, and the Environmental Checklist serve as the substitute documents for this project. The project itself is the establishment of a TMDL for bacteria in Ballona Creek, Ballona

Estuary, and Sepulveda Channel. While the Regional Board has no discretion to not establish a TMDL (the TMDL is required by federal law) or for determining the water quality standard to be applied (the Basin Plan establishes the numeric water quality objectives that must be implemented), the Board does exercise discretion in assigning waste load allocations and load allocations, determining the program of implementation, and setting various milestones in achieving the numeric water quality standards established in the Basin Plan.

16. A CEQA Scoping hearing was conducted on June 12, 2003 at the Los Angeles Regional Water Quality Control Board, 320 W. 4th Street, Los Angeles, CA 90013. A notice of the CEQA Scoping hearing was sent to interested parties including cities and/or counties with jurisdiction in or bordering the Ballona Creek watershed.

17. The lengthy implementation period allowed by the TMDL, will allow many compliance approaches to be pursued. In preparing the accompanying CEQA substitute documents, the Regional Board has considered the requirements of Public Resources Code section 21159 and California Code of Regulations, title 14, section 15187, and intends the substitute documents to serve as a tier 1 environmental review. Nearly all of the compliance obligations will be undertaken by public agencies that will have their own obligations under CEQA. Project level impacts will need to be considered in any subsequent environmental analysis performed by other public agencies, pursuant to Public Resources Code section 21159.2. If not properly mitigated at the project level, there could be adverse environmental impacts. The substitute documents for this TMDL, and in particular the Environmental Checklist and staff's responses to comments, identify broad mitigation approaches that should be considered at the project level. Consistent with CEQA, the substitute documents do not engage in speculation or conjecture and only consider the reasonably foreseeable environmental impacts of the methods of compliance, the reasonably foreseeable feasible mitigation measures, and the reasonably foreseeable alternative means of compliance, which would avoid or eliminate the identified impacts.

18. The proposed amendment could have a significant adverse effect on the environment. However, there are feasible alternatives, feasible mitigation measures, or both that would substantially lessen any significant adverse impact. The public agencies responsible for those parts of the project can and should incorporate such alternatives and mitigation into any subsequent projects or project approvals. Possible alternatives and mitigation are described in the CEQA substitute documents, specifically the TMDL technical report and the Environmental Checklist. To the extent the alternatives, mitigation measures, or both are not deemed feasible by those agencies, the necessity of implementing the federally required bacteria TMDL and reducing the elevated bacteria densities from Ballona Creek, Ballona Estuary, and Sepulveda Channel (an action required to achieve the express, national policy of the Clean Water Act) outweigh the unavoidable adverse environmental effects.

19. The regulatory action meets the "Necessity" standard of the Administrative Procedures Act, Government Code, Section 11353, Subdivision (b). As specified above, federal regulations require that TMDLs be incorporated into the water quality management plan. The Regional Board's Basin Plan is the Regional Board's component of the water quality management plan, and the Basin Plan is how the Regional Board takes quasi-legislative, planning actions. Moreover, the TMDL is a program of implementation for existing water quality objectives, and is, therefore, appropriately a component of the Basin Plan under Water Code section 13242. The necessity of developing a TMDL is established in the TMDL staff report, the section 303(d) list, and the data contained in the administrative record documenting the bacteria impairments of the Ballona Creek, Ballona Estuary, and Sepulveda Channel.

20. The Basin Plan amendment incorporating a TMDL for Bacteria Densities in Ballona Creek, Ballona Estuary, and Sepulveda Channel must be submitted for review and approval by the State Water Resources Control Board (State Board), the State Office of Administrative Law (OAL), and the USEPA. The Basin Plan amendment will become effective upon approval by OAL and USEPA. A Notice of Decision will be filed.

21. If during its approval process Regional Board staff, the SWRCB or OAL determines that minor, non-substantive corrections to the language of the amendment are needed for clarity or consistency, the Executive Officer may make such changes, and shall inform the Board of any such changes.

THEREFORE, be it resolved that pursuant to sections 13240 and 13242 of the Water Code, the Regional Board hereby amends the Basin Plan as follows:

1. Pursuant to sections 13240 and 13242 of the California Water Code, the Regional Board, after considering the entire record, including oral testimony at the hearing, hereby adopts the amendments to Chapters 3 and 7 of the Water Quality Control Plan for the Los Angeles Region, as set forth in Attachment A hereto, to incorporate the elements of the bacteria TMDL for Ballona Creek, Ballona Estuary, and Sepulveda Channel.

2. The Executive Officer is directed to forward copies of the Basin Plan amendment to the State Board in accordance with the requirements of section 13245 of the California Water Code.

3. The Regional Board requests that the State Board approve the Basin Plan amendment in accordance with the requirements of sections 13245 and 13246 of the California Water Code and forward it to OAL and the USEPA.

4. If during its approval process the State Board or OAL determines that minor, non-substantive corrections to the language of the amendment are needed for clarity or consistency, the Executive Officer may make such changes, and shall inform the Board of any such changes.

5. The Executive Officer is authorized to sign a Certificate of Fee Exemption.

I, Jonathan S. Bishop, Executive Officer, do hereby certify that the foregoing is a full, true, and correct copy of a resolution adopted by the California Regional Water Quality Control Board, Los Angeles Region, on June 8, 2006.

Chief Deputy for

Jonathan S. Bishop
Executive Officer

As adopted on June 8, 2006

Attachment A to Resolution No. 06-011

Amendment to the Water Quality Control Plan – Los Angeles Region to incorporate the TMDL for Bacterial Indicator Densities in Ballona Creek, Ballona Estuary, and Sepulveda Channel.

Adopted by the California Regional Water Quality Control Board, Los Angeles Region on June 8, 2006.

Amendments:

Table of Contents
Add:

Chapter 7. Total Maximum Daily Loads (TMDLs) Summaries
7-21 Ballona Creek, Ballona Estuary and Sepulveda Channel Bacteria TMDL

List of Figures, Tables and Inserts
Add:

Chapter 7. Total Maximum Daily Loads (TMDLs)
Tables
7-21 Ballona Creek, Ballona Estuary and Sepulveda Channel Bacteria TMDL
7-21.1. Ballona Creek, Ballona Estuary and Sepulveda Channel Bacteria TMDL: Elements
7-21.2a. Ballona Creek, Ballona Estuary and Sepulveda Channel Bacteria TMDL: Final Allowable Exceedance Days by Reach
7.21.2b. Ballona Creek, Ballona Estuary and Sepulveda Channel Bacteria TMDL: WLAs and LAs for tributaries to the Impaired Reaches.
7-21.3. Ballona Creek, Ballona Estuary and Sepulveda Channel Bacteria TMDL: Significant Dates

Chapter 7. Total Maximum Daily Loads (TMDLs) Summaries, Section 7-21 (Ballona Creek, Ballona Estuary, and Sepulveda Channel Bacteria TMDL)

This TMDL was adopted by the Regional Water Quality Control Board on June 8, 2006.

This TMDL was approved by:

The State Water Resources Control Board on [Insert Date].
The Office of Administrative Law on [Insert Date].
The U.S. Environmental Protection Agency on [Insert Date].

The following table includes all the elements of this TMDL.

Table 7-21.1. Ballona Creek, Estuary, and Tributaries s Bacteria TMDL: Elements

Element	Key Findings and Regulatory Provisions
Problem Statement	Elevated bacterial indicator densities are causing impairment of the water contact recreation (REC-1) beneficial use designated for Ballona Estuary and Sepulveda Channel, limited water contact recreation (LREC) designated for Ballona Creek Reach 2, and non-contact recreation (REC-2) beneficial uses of Ballona Creek Reach 1. Recreating in waters with elevated bacterial indicator densities has long been associated with adverse human health effects. Specifically, local and national epidemiological studies compel the conclusion that there is a causal relationship between adverse health effects and recreational water quality, as measured by bacterial indicator densities.
Numeric Target *(Interpretation of the numeric water quality objective, used to calculate the waste load allocations)*	The TMDL has a multi-part numeric target based on the bacteriological water quality objectives for marine and fresh water to protect the contact and non-contact recreation uses. These targets are the most appropriate indicators of public health risk in recreational waters. These bacteriological objectives are set forth in Chapter 3 of the Basin Plan.[1] The objectives are based on four bacterial indicators and include both geometric mean limits and single sample limits. The Basin Plan objectives that serve as the numeric targets for this TMDL are: In Marine Waters Designated for Water Contact Recreation (REC-1) 1. Geometric Mean Limits a. Total coliform density shall not exceed 1,000/100 ml. b. Fecal coliform density shall not exceed 200/100 ml. c. Enterococcus density shall not exceed 35/100 ml. 2. Single Sample Limits a. Total coliform density shall not exceed 10,000/100 ml. b. Fecal coliform density shall not exceed 400/100 ml. c. Enterococcus density shall not exceed 104/100 ml. d. Total coliform density shall not exceed 1,000/100 ml, if the ratio of fecal-to-total coliform exceeds 0.1. In Fresh Waters Designated for Water Contact Recreation (REC-1) 1. Geometric Mean Limits a. *E. coli* density shall not exceed 126/100 ml. b. Fecal coliform density shall not exceed 200/100 ml. 2. Single Sample Limits a. *E. coli* density shall not exceed 235/100 ml. b. Fecal coliform density shall not exceed 400/100 ml.

[1] The bacteriological objectives were revised by a Basin Plan amendment adopted by the Regional Board on October 25, 2001, and subsequently approved by the State Water Resources Control Board, the Office of Administrative Law and finally by U.S. EPA on September 25, 2002.

Element	Key Findings and Regulatory Provisions
	In Fresh Waters Designated for Limited Water Contact Recreation (LREC-1)[2] 1. Geometric Mean Limits a. *E. coli* density shall not exceed 126/100 ml. b. Fecal coliform density shall not exceed 200/100 ml. 2. Single Sample Limits a. *E. coli* density shall not exceed 576/100 ml. In Fresh Waters Designated for Non-Contact Water Recreation (REC-2) 1. Geometric Mean Limits a. Fecal coliform density shall not exceed 2000/100 ml. 2. Single Sample Limits a. Fecal coliform density shall not exceed 4000/100 ml. The targets apply throughout the year. Determination of attainment of the targets will be at in-stream monitoring sites to be specified in the compliance monitoring report. Implementation of the above REC-1 and LREC-1 bacteria objectives and the associated TMDL numeric targets is achieved using a 'reference system/anti-degradation approach' rather than the alternative 'natural sources exclusion approach subject to antidegradation policies' or strict application of the single sample objectives. As required by the CWA and Porter-Cologne Water Quality Control Act, Basin Plans include beneficial uses of waters, water quality objectives to protect those uses, an anti-degradation policy, collectively referred to as water quality standards, and other plans and policies necessary to implement water quality standards. This TMDL and its associated waste load allocations, which shall be incorporated into relevant permits, and load allocations are the vehicles for implementation of the Region's standards. The 'reference system/anti-degradation approach' means that on the basis of historical exceedance levels at existing monitoring locations, including a local reference beach within Santa Monica Bay, a certain number of daily exceedances of the single sample bacteria objectives are permitted. The allowable number of exceedance days is set such that (1) bacteriological water quality at any site is at least as good as at a designated reference site within the watershed and (2) there is no degradation of existing bacteriological water quality. This approach recognizes that there are natural sources of bacteria that may cause or contribute to exceedances of the single sample objectives and that it is not the intent of the Regional Board to require treatment or diversion of natural coastal creeks or to require treatment of natural sources of bacteria from undeveloped areas.

[2] The bacteriological objectives for the LREC-1 use designation were provided in a Basin Plan Amendment adopted by State Board on January 20, 2005, and subsequently approved by the Office of Administrative Law and finally by U.S. EPA on February 17, 2006

Element	Key Findings and Regulatory Provisions
	The geometric mean targets may not be exceeded at any time. The rolling 30-day geometric means will be calculated on each day. If weekly sampling is conducted, the weekly sample result will be assigned to the remaining days of the week in order to calculate the daily rolling 30-day geometric mean. For the single sample targets, each existing monitoring site is assigned an allowable number of exceedance days for three time periods (1) summer dry-weather (April 1 to October 31), (2) winter dry-weather (November 1 to March 31), and (3) wet-weather (defined as days with 0.1 inch of rain or greater and the three days following the rain event.) Implementation of the REC-2 target will be as specified in the Basin Plan. The REC-2 bacteria objectives allow for a 10% exceedance frequency of the single sample limit in samples collected during a 30-day period. This allowance, which is based on an acceptable level of health risk, will be applied in lieu of the allowable exceedance days discussed earlier. As with the other REC-1 and LREC-1 objectives, the geometric mean target for REC-2, which is based on a rolling 30-day period, will be strictly adhered to and may not be exceeded at any time.
Source Analysis	The major contributors of flows and associated bacteria loading to Ballona Creek and Estuary, are dry- and wet-weather urban runoff discharges from the storm water conveyance system. Run-off to Ballona Creek is regulated as a point source under the Los Angeles County MS4 Permit, the Caltrans Storm Water Permit, and the General Construction and Industrial Storm Water Permits. In addition to these regulated point sources, the Ballona Estuary receives input from the Del Rey Lagoon and Ballona Wetlands through connecting tide gates. Preliminary data suggest that the Ballona Wetlands are a sink for bacteria from Ballona Creek and it is therefore not considered a source in this TMDL. Inputs to Ballona Estuary from Del Rey Lagoon, are considered non-point sources of bacterial contamination. This waterbody may be considered for a natural source exclusion if its contributing bacteria loads are determined to be as a result of wildlife in the area, as opposed to anthropogenic inputs. The TMDL will require a source identification study for the lagoon in order to apply the natural source exclusion. Other nonpoint sources in Ballona Creek and Estuary include natural sources from birds, waterfowl and other wildlife. Data do not currently exist to quantify the extent of the impact of wildlife on bacteria water quality in the Estuary.
Loading Capacity	The loading capacity is defined in terms of bacterial indicator densities, which is the most appropriate for addressing public health risk, and is equivalent to the numeric targets, listed above.
Waste Load Allocations *(for point sources)*	The Los Angeles County MS4 and Caltrans storm water permittees and co-permittees are assigned waste load allocations (WLAs) expressed as the number of daily or weekly sample days that may exceed the single sample targets equal to the TMDLs established for the impaired reaches (see Table 7.21.2a), and Waste Load Allocations assigned to waters tributary to impaired reaches (Table 7.21.2b). Waste load allocations are expressed as allowable exceedance days because the bacterial density and frequency of single sample

Element	Key Findings and Regulatory Provisions
	exceedances are the most relevant to public health protection. For each monitoring site, allowable exceedance days are set on an annual basis as well as for three time periods. These three periods are: 1. summer dry-weather (April 1 to October 31) 2. winter dry-weather (November 1 to March 31) 3. wet-weather days (defined as days of 0.1 inch of rain or more plus three days following the rain event). The County of Los Angeles, Caltrans, and the Cities of Los Angeles, Culver City, Beverly Hills, Inglewood, West Hollywood, and Santa Monica are the responsible jurisdictions and responsible agencies[3] for the Ballona Creek Watershed. The responsible jurisdictions and responsible agencies within the watershed are jointly responsible for complying with the waste load allocation in each reach. For the single sample objectives of the impaired REC-1 and LREC-1 reaches, the proposed WLA for summer dry-weather are zero (0) days of allowable exceedances, and those for winter dry-weather and wet-weather are three (3) days and seventeen (17) days of exceedance, respectively. In the instances where more than one single sample objective applies, exceedance of any one of the limits constitutes an exceedance day. The proposed waste load allocation for the rolling 30-day geometric mean for the responsible agencies and jurisdictions is zero (0) days of allowable exceedances. For the single sample objectives of the impaired REC-2 reach, the proposed WLA for all periods is a 10% exceedance frequency of the REC-2 single sample water quality objectives. The proposed waste load allocation for the rolling 30-day geometric mean for the responsible agencies and jurisdictions is zero (0) days of allowable exceedances. In addition to assigning TMDLs for the impaired reaches, Waste Load Allocations and Load Allocations are assigned to the tributaries to these impaired reaches. These WLAs and LAs are to be met at the confluence of each tributary and its downstream reach (see Table 7.21.2b).
Load Allocations *(for nonpoint sources)*	Load allocations are expressed as the number of daily or weekly sample days that may exceed the single sample targets identified under "Numeric Target" at a monitoring site, along with a rolling 30-day geometric mean. Load allocations are expressed as allowable exceedance days because the bacterial density and frequency of single sample exceedances are the most relevant to public health protection. Del Rey Lagoon is considered a nonpoint source and is therefore subject to load allocations. The proposed LA for summer dry-weather are zero (0) days of allowable exceedances, and those for winter dry-weather and wet-weather are three (3) days and seventeen (17) days of exceedance, respectively. In the instances where more than one single sample objective applies, exceedance of any one of the limits constitutes an exceedance day. The proposed load allocation for the rolling 30-day geometric mean for the responsible agencies and

[3] For the purposes of this TMDL, "responsible jurisdictions and responsible agencies" are defined as (1) local agencies that are permittees or co-permittees on a municipal storm water permit, (2) local or state agencies that have jurisdiction over Ballona Creek and Estuary, and (3) the California Department of Transportation pursuant to its storm water permit.

Element	Key Findings and Regulatory Provisions
	jurisdictions is zero (0) days of allowable exceedances (see Table 7.21.2a). The City of Los Angeles is the responsible jurisdiction for the Del Rey lagoon, and is responsible for complying with the assigned load allocations presented in Table 7.21.2b at the tide gate(s) between the Lagoon and the Estuary. If other unidentified nonpoint sources are directly impacting bacteriological water quality and causing an exceedance of the numeric targets, within the Estuary, the permittee(s) under the Municipal Storm Water NPDES Permits are not responsible through these permits. However, the jurisdiction or agency adjacent to the monitoring location may have further obligations to identify such sources.
Implementation	The regulatory mechanisms used to implement the TMDL will include the Los Angeles County Municipal Storm Water NPDES Permit (MS4), the Caltrans Storm Water Permit, general NPDES permits, general industrial storm water permits, general construction storm water permits, and the authority contained in Sections 13263 and 13267 of the Water Code. Each NPDES permit assigned a WLA shall be reopened or amended at re-issuance, in accordance with applicable laws, to incorporate the applicable WLAs as a permit requirement. Each responsible jurisdictions and agency will be required to meet the storm water waste load allocations shared by the LA County MS4 and Caltrans permittees at the designated TMDL effectiveness monitoring points. An iterative implementation approach using a combination of non-structural and structural BMPs may be used to achieve compliance with the waste load allocations. The administrative record and the fact sheets for the MS4 and Caltrans storm water permits must provide reasonable assurance that the BMPs selected will be sufficient to implement the waste load allocation. Load allocations for nonpoint sources will be incorporated into Waste Discharge Requirements and MOUs with the responsible jurisdictional agencies. This TMDL will be implemented in two phases over a ten-year period (see Table 7-21.3). Within six years of the effective date of the TMDL, compliance with the allowable number of summer dry-weather (April 1 to October 31), winter dry-weather exceedance days (November 1 to March 31) and the rolling 30-day geometric mean targets for both periods must be achieved. Within ten years of the effective date of the TMDL, compliance with the allowable number of wet-weather exceedance days and rolling 30-day geometric mean targets must be achieved. In order to clearly justify an extended implementation schedule beyond 10 years and up to 14 years from the effective date of the TMDL, the responsible agencies are required to submit additional quantifiable analyses as described below to demonstrate (1) the proposed plans will meet the final WLAs and (2) the proposed implementation actions will achieve multiple water quality benefits and other public goals. The types of approaches proposed coupled with quantifiable estimates of the integrated water resources benefits of the proposed structural and non-structural BMPs included in the Implementation Plan would provide the obligatory demonstration that an integrated water resources approach is being

Element	Key Findings and Regulatory Provisions
	pursued. This demonstration shall include numeric estimates of the benefits, including but not limited to reductions in other pollutants, groundwater recharged, acres of multi-use projects and water (e.g. urban runoff) beneficially reused. The responsible jurisdictions and the responsible agencies must submit a report to the Executive Officer (see Table 7-21.3) describing how they intend to comply with the dry-weather and wet-weather WLAs. As the primary jurisdiction, the City of Los Angeles is responsible for submitting the implementation plan report described above. In addition, as the responsible agency for Del Rey Lagoon, the City of Los Angeles must submit a report detailing how it intends to comply with the load allocations assigned to this waterbody. Alternatively, the City of Los Angeles may submit data clearly demonstrating that Del Rey Lagoon is not a source, for the Regional Board's consideration.. The Regional Board intends to reconsider this TMDL, within 4 years of its effective date to incorporate modifications to the WLAs based on results of the scheduled reconsideration of the Santa Monica Bay (SMB) beaches TMDLs. The SMB beaches TMDLs are scheduled to be reconsidered in four years to re-evaluate the allowable winter dry-weather and wet-weather exceedance days based on additional data on bacterial indicator densities in the wave wash; to re-evaluate the reference system selected to set allowable exceedance levels; to re-evaluate the reference year used in the calculation of allowable exceedance days, and to re-evaluate the need for revision of the geometric mean implementation provision. The Regional Board also intends to re-asses the WLAs for Benedict Canyon Channel, Sepulveda Channel, and Centinela Creek based on results of the required compliance monitoring, and/or any voluntary beneficial use investigations.
Margin of Safety	By directly applying the numeric water quality standards and implementation procedures as Waste Load Allocations, there is little uncertainty about whether meeting the TMDLs will result in meeting the water quality standards.
Seasonal Variations and Critical Conditions	Seasonal variations are addressed by developing separate waste load allocations for three time periods (summer dry-weather, winter-dry weather, and wet-weather) based on public health concerns and observed natural background levels of exceedance of bacterial indicators. The critical condition for bacteria loading to the Ballona Creek, Ballona Estuary, and Sepulveda Channel is during wet weather when monitoring data indicate greater exceedance probabilities of the single sample bacteria objectives than during dry-weather. The Santa Monica Bay Beaches Bacteria TMDL identified the critical condition within wet weather more specifically, in order to set the allowable number of exceedances of the single sample limit days. The 90^{th} percentile storm year in terms of wet days was used as the reference year. The 90^{th} percentile year was selected for several reasons. First, selecting the 90^{th} percentile year avoids an untenable situation where the reference system is frequently out of compliance. Second, selecting the 90^{th} percentile year allows responsible jurisdictions and responsible agencies to plan for a 'worst-case scenario', as a critical condition is intended to do

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Element	Key Findings and Regulatory Provisions
Monitoring	The TMDL effectiveness monitoring program will assess attainment of the allowable exceedances for Ballona Creek, Ballona Estuary, and Sepulveda Channel, and the WLAs for the tributaries. Responsible jurisdictions and responsible agencies shall conduct daily or systematic weekly sampling at a minimum of two locations within Ballona Estuary and Reach 2 of Ballona Creek, at least one location each in Reach 1 of Ballona Creek and Sepulveda Channel, and at the confluence with Centinela Creek and Benedict Canyon Channel, to determine compliance. Similar monitoring at the connecting tide gates of Del Rey Lagoon is also required. Where monitoring locations are located at or close to the boundary of two reaches, data from sampling points will also be used to assess the immediate downstream reach. This will ensure that the downstream reaches, which have more stringent water quality objectives, are adequately protected. If the number of exceedance days is greater than the allowable number of exceedance days in the REC-1 and LREC-1 waters, and/or the frequency of exceedance is greater than 10% in the REC-2 waters, the responsible jurisdictions and/or responsible agencies shall be considered not to be attaining the TMDLs and/or assigned allocations (non-attaining). Responsible jurisdictions or agencies shall not be deemed non-attaining if the investigation described in the paragraph below demonstrates that bacterial sources originating within the jurisdiction of the responsible agency have not caused or contributed to the exceedance. If an in-stream location is non-attaining as determined in the previous paragraph, the Regional Board shall require responsible agencies to initiate an investigation, which at a minimum shall include daily sampling at the existing monitoring location until all single sample events meet bacteria water quality objectives.
Special Studies	Should the jurisdictional agency for Del Rey Lagoon opt for the natural source exclusion, the TMDL requires that a separate bacteria source identification study be conducted to determine its eligibility.. The study should identify all probable sources of bacteria loads, their estimated contributions to the Lagoon, and a determination of the frequency of exceedances of the single sample bacteria objectives caused by the identified natural sources.

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Table 7.21.2a: Ballona Creek, Ballona Estuary and Sepulveda Channel Bacteria TMDL: Final Allowable Exceedance Days by Reach

Time Period	Ballona Estuary, Ballona Creek Reach 2, and Sepulveda Channel *	Ballona Creek Reach 1**
Summer Dry-Weather (April 1 to October 31)	Zero (0) exceedance days based on the applicable Single Sample Bacteria Water Quality Objectives Zero (0) exceedance days based on the Rolling 30-Day Geometric Mean Bacteria Water Quality Objectives	No more than 10% of the Single Sample Bacteria Water Quality Objectives Zero (0) exceedance days based on the Rolling 30-Day Geometric Mean Bacteria Water Quality Objectives
Winter Dry-Weather (November 1-March 31)	Three (3) exceedance days based on the applicable Single Sample Bacteria Water Quality Objectives Zero (0) exceedance days based on the Rolling 30-Day Geometric Mean Bacteria Water Quality Objectives	No more than 10% of the Single Sample Bacteria Water Quality Objectives Zero (0) exceedance days based on the Rolling 30-Day Geometric Mean Bacteria Water Quality Objectives
Wet-Weather (days with ≥0.1 inch of rain + 3 days following the rain event)	17*** exceedance days based on the applicable Single Sample Bacteria Water Quality Objectives Zero (0) exceedance days based on the Rolling 30-Day Geometric Mean Bacteria Water Quality Objectives	No more than 10% of the Single Sample Bacteria Water Quality Objectives Zero (0) exceedance days based on the Rolling 30-Day Geometric Mean Bacteria Water Quality Objectives

* Exceedance days for Ballona Estuary based on REC-1 marine water numeric targets; for Ballona Creek Reach 2 based on LREC-1 freshwater numeric targets; and for Sepulveda Channel, based on fresh water REC-1 numeric targets

**Exceedance frequency for Ballona Creek Reach 1 based on freshwater REC-2 numeric targets

*** In Reach 2, the greater of the allowable exceedance days under the reference system approach or high flow suspension shall apply.

Table 7.21.2b: Ballona Creek, Ballona Estuary and Sepulveda Channel Bacteria TMDL: WLAs and LAs for tributaries to the Impaired Reaches.

Tributary	Point of Application	Water Quality Objectives	Waste Load Allocation (No. exceedance days)
Ballona Creek Reach 1	At confluence with Reach 2	LREC-1 Freshwater	For single sample objectives: *(0) summer dry weather,* *(3) winter dry weather* *(17*) winter wet weather* For geometric mean objectives: *(0) for all periods*
Benedict Canyon Channel	At confluence with Reach 2	LREC-1 Freshwater	For single sample objectives: *(0) summer dry weather,* *(3) winter dry weather* *(17*) winter wet weather* For geometric mean objectives: *(0) for all periods*
Ballona Creek Reach 2	At confluence with Ballona Estuary	REC-1 Marine water	For single sample objectives: *(0) summer dry weather,* *(3) winter dry weather* *(17) winter wet weather* For geometric mean objectives: *(0) for all periods*
Centinela Creek	At confluence with Ballona Estuary	REC-1 Marine water	For single sample objectives: *(0) summer dry weather,* *(3) winter dry weather* *(17) winter wet weather* For geometric mean objectives: *(0) for all periods*
Del Rey Lagoon	At confluence with Ballona Estuary	REC-1 Marine water	For single sample objectives: *(0) summer dry weather,* *(3)winter dry weather* *(17) winter wet weather* For geometric mean objectives: *(0) for all periods*

*At the confluence with Reach 2, the greater of the allowable exceedance days under the reference system approach or high flow suspension shall apply.

Sepulveda Channel was not assigned a waste load allocation at its confluence with Reach 2 since the TMDL requires the more stringent REC-1 objectives to be met in this waterbody, which should lead to the attainment of the less stringent LREC-1 objectives of the downstream reach.

Table 7.21.3 Ballona Creek, Ballona Estuary and Sepulveda Channel Bacteria TMDL: Significant Dates

Date	Action
Responsible Jurisdictions for the Waste Load Allocations	
12 months after the effective date of the TMDL	Responsible jurisdictions and responsible agencies must submit, for Regional Board approval, a comprehensive bacteria water quality monitoring plan for the Ballona Creek Watershed. The plan must be approved by the Executive Officer before the monitoring data can be considered during the implementation of the TMDL. The plan must provide for analyses of all applicable bacteria indicators for which the Basin Plan and subsequent amendments have established objectives The plan must also include a minimum of two sampling locations (mid-stream and downstream) in Ballona Estuary, Ballona Creek (Reach 1 and 2), and their tributaries. The draft monitoring report shall be made available for public comment and the Executive Officer shall accept public comments for at least 30 days. Once the coordinated monitoring plan is approved by the Executive Officer, monitoring shall commence within 6 months.
$2^1/_2$ years after the effective date of the TMDL	Responsible jurisdictions and agencies must provide a draft Implementation Plan to the Regional Board outlining how each intends to cooperatively achieve compliance with the dry-weather and wet-weather TMDL Waste Load Allocations. The report shall include implementation methods, an implementation schedule, and proposed milestones. The description of the implementation methods and milestones shall include a technically defensible quantitative linkage to the interim and final waste load allocations (WLAs). The linkage should include target reductions in stormwater runoff and/or fecal indicator bacteria. The plan shall include quantitative estimates of the water quality benefits provided by the proposed structural and non-structural BMPs. Estimates should address reductions in exceedance days, bacteria concentration and loading, and flow in the drain and at each beach compliance monitoring location. As part of the draft plan, responsible agencies must submit results of all special studies and/or Environmental Impact Assessments, designed to determine feasibility of any strategy that requires diversion and/or reduction of Creek flows. If a responsible jurisdiction or agency is requesting a longer schedule for wet-weather compliance based on an integrated approach, the plan must include a clear demonstration that the plan meets the criteria of an IWRA, and a clear demonstration of the need for the proposed schedule. Compliance with the wet-weather allocations shall be as soon as possible but under no circumstances shall it exceed the time frame adopted in the

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Date	Action
	TMDL for non-integrated approaches or for an integrated approach. The draft Plan shall be made available for public comment and the Executive Officer shall accept public comments for at least 30 days.
3 months after receipt of Regional Board comments on the draft plan	Responsible jurisdictions and agencies submit a Final Implementation Plan to the Regional Board.
Responsible agencies for Load Allocations	
1 year after the effective date of the TMDL	Responsible agencies must submit, for Regional Board approval, separate comprehensive bacteria water quality monitoring plans for inputs from Del Rey Lagoon and the Ballona Wetlands to the Ballona Estuary. Each plan must be approved by the Executive Officer before the monitoring data can be considered during the implementation of the TMDL. The plan must provide for analyses of all applicable bacteria indicators for which the Basin Plan and subsequent amendments have established objectives The plan must also include a minimum of one sampling location at the connecting tide gate(s). The draft monitoring reports shall be made available for public comment and the Executive Officer shall accept public comments for at least 30 days. Once a coordinated monitoring plan is approved by the Executive Officer, monitoring shall commence within 6 months.
3 years after the effective date of the TMDL.	If the responsible agency for the Del Rey Lagoon intends to pursue a natural source exclusion, it shall submit the results of separate natural source study for the Lagoon to the Executive Officer of the Regional Board. The study shall include a comprehensive assessment of all sources of bacteria loads to the Lagoon and estimates of their individual contributions. In addition, a determination of the number of exceedance days caused by these sources should be made These studies shall be made available for public comment and the Executive Officer shall accept public comments for at least 30 days.
Responsible Agencies for WLAs and LAs* *(*Only if not eligible for natural source exclusion(s)*	
4 years after the effective date of the TMDL:	The Regional Board shall reconsider this TMDL to: (1) Re-assess the allowable winter dry-weather and wet-weather exceedance days based on a re-evaluation of the selected reference watershed and consideration of other reference watersheds that may better represent reaches of Ballona

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Date	Action
	Creek and Estuary, (2) Consider whether the allowable winter dry-weather and wet-weather exceedance days should be adjusted annually dependent on the rainfall conditions and an evaluation of natural variability in exceedance levels in the reference system(s), (3) Re-evaluate the reference year used in the calculation of allowable exceedance days, and (4) Re-evaluate whether there is a need for further clarification or revision of the geometric mean implementation provision. (5) Consider natural source exclusions for bacteria loading from Del Rey Lagoon and the Ballona Wetlands based on results of the source identification study. (6) Re-assess WLAs for Benedict Canyon Channel, Sepulveda Channel, and Centinela Creek based on results of the required compliance monitoring, and/or any voluntary beneficial use investigations.
6 years after the effective date of the TMDL:	Achieve compliance with the allowable exceedance days for summer and winter dry-weather as set forth in Table 6-1 and rolling 30-day geometric mean targets.
10 years after effective date of the TMDL or, if an Integrated Water Resources Approach is implemented, up to July 15, 2021.*	Achieve compliance with the allowable exceedance days as set forth in Table 6-1 and rolling 30-day geometric mean targets during wet-weather.

*July 15, 2021 is the final compliance date of the Santa Monica Bay Beaches Bacteria Wet-Weather TMDL.

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APPENDIX L

Laboratory Safety

The collection and analysis of environmental samples involves contact with samples that may contain agents that pose a microbiological hazard. The primary means of exposure to these microbiological hazards involve body contact during sample collection and hand-mouth or nose contact while handling the samples. Personal protective measures are mandatory while working in the field and laboratory. Following are some key steps to be followed by all laboratory analysts:

a. Assure that all persons wear appropriate eye protection when toxic materials (chemicals or biochemicals) are handled. Contact lenses should not be worn when working with chemicals.
b. Wear appropriate gloves when the potential for contact with toxic materials exists; inspect gloves before each use, wash them before removal, and replace them periodically.
c. Persons doing sampling must wear boots. The boots must be cleaned before entering the building. Boots cannot be worn in the lunchroom, under any circumstances. Steel-toed chemical resistant boots should be worn for the harshest environments, where there is also risk of injury to the foot and toes.
d. Use any other protective and emergency apparel and equipment as appropriate.
e. Remove laboratory coats immediately on significant contamination.

In addition, persons who work in biological laboratories are often at risk of exposing themselves to a number of infectious agents, especially those known to be indigenous to wastewater. Most persons trained in biological and especially microbiological fields usually are aware of the risks involved, and even if precautions are taken, most of the work-related infections are due to certain practices conducted in the laboratory resulting in the generation of aerosols or through cutaneous pathways. The following guidelines are designed to prevent any exposure of personnel to infectious agents.

1. General chemical hygiene practices apply as well to the biological laboratories.
2. All work areas must be disinfected before and after all laboratory operations.
3. Hazardous areas and receptacles of contaminated items are to be marked with a biohazard sign.
4. No eating or drinking in the laboratory. No food or drink is to be stored in laboratory refrigerators, incubators or on bench tops.
5. Store personal effects outside the microbiology laboratory area to prevent contamination. Manager and supervisors are responsible for enforcing this rule.
6. It is policy to wear a lab coat while working in the microbiology lab. Lab coats and street clothes should be stored separately. Lab coats are prohibited in the lunchroom.

7. Latex or plastic gloves are to be provided and used by employees.
8. Always wash your hands thoroughly after handling sewage, sludge, or receiving water samples of any source before handling food or leaving the lab. “All” samples should be treated as potentially hazardous. Germicidal soap is to be available to all employees, and should be kept in stock.
9. Laboratory workers should not touch their hands to their face, especially the eyes, nose, and mouth when working with wastewater and sludge samples.
10. For workers who handle wastewater and its byproducts, it is recommended that they have been vaccinated for polio and tetanus. Persons in poor health and at risk of infection should inform their supervisor, and arrange for an improvement in their personal protection.
11. Handle all microorganisms as if they are pathogenic. The principle of sterile technique should be understood and applied during the handling of cultures and their related equipments.
12. Never pipette by mouth. Use bulbs or other mechanical means to draw up the liquid. Discard all used pipettes into a jar containing disinfectant solution for decontamination before washing them.
13. Avoid generation of aerosols during operations such as inoculation, pipetting, mixing, or centrifuging.
14. Equipment:
    a. Microscopes, colony counters, etc. are to be kept in the work area and be dust free; they are to be cleaned after use.
    b. Water baths should be kept free of growth deposits.
    c. Autoclaves, hot air sterilizing ovens, and water distilling equipment and centrifuges should be cleaned regularly to ensure safe operating.
    d. Employees are to be trained in autoclave operation and operating instructions posted near each instrument.
    e. Performance checks of autoclaves and hot air sterilizers should be conducted with the use of spore strips, spore ampoules, indicators, etc.
15. Safety cabinets of the appropriate type and class are to be supplied, maintained, and used.
16. Personnel are to be trained in the proper procedures for handling lyophilized (freeze-dried) cultures when used.
17. Employees should use the provided bottle carriers when moving reagents, acids, and solvents through the building.
18. Laboratory personnel must follow labeling protocols in the laboratory to prevent mix-ups of reagents, and when possible use the pre-labeled or permanently labeled bottles. Secondary containers are to be labeled as well.
19. In the event of a spill, all possible contaminated surfaces and tools are to be disinfected and the absorbent material placed in a biohazard bag for disposal.
20. All contaminated plates and Quanti-trays are to be autoclaved in biohazard bags at the end of the analysis and then disposed of in the labeled bags as regular trash.
21. Sterilize biological waste materials and contaminated equipment (cultures, glassware, etc.) before washing, storage, or disposal by autoclaving or decontaminating.

22. Eliminate flies and other insects to prevent contamination vectors of sterile equipment, media, samples, cultures, and infection of personnel (i.e., provide screens on windows and doors to outside if there is no air conditioning).

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APPENDIX M.

Participating Organizations and Contacts

Responsible Agencies

	Contact	Phone	E-mail
City of Los Angeles	Reza Iranpour	(213) 485-0577	reza.iranpour@lacity.org
	Gerry McGowen	(310) 648-5611	gerald.mcgowen@lacity.org
County of Los Angeles	Angela George	(626) 458-4341	ageorge@dpw.lacounty.gov
	Nathan Stevenson	(626) 458-4368	nstevenson@dpw.lacounty.gov
Beverly Hills	Josette Descalzo	(310) 285-2498	jdescalzo@beverlyhills.org
Culver City	Steven Finton	(310) 253-6406	steven.finton@culvercity.org
Inglewood	Salvador Ramirez	(626) 396-9424	sramirez@tecsenv.com
West Hollywood	Jan Harmon	(323) 848-6499	Jharmon@weho.org
Santa Monica	Neal Shapiro	(310) 458-8223	neal.shapiro@smgov.net
Caltrans	Bob Wu	(213) 897-8936	robert_wu@dot.ca.gov

Other Participants

Regional Board	Contact	Phone	E-mail
	Ginachi Amah	(213) 576-6685	gamah@waterboards.ca.gov
Heal the Bay	Mark Gold	(310) 453-0395	mgold@healthebay.org
SM Baykeeper	Carlos Carreon	(310) 305-9645	sandpiper@smbaykeeper.org

APPENDIX N
INTERVIEW DOCUMENTATION RELATED TO TIDE GATES

Watearth
Water Resources + Green Infrastructure

TELE-CON

TO:	Luis Valenzuela-Mariposa (626) 705-0622	PROJECT:	City of LA Venice Auxiliary Pumping
FROM:	Jennifer Buchanan	JOB NO.	
DATE:	September 16, 2015	TIME:	4:10 pm

SUBJECT: Operation of Washington Street Tide Gates

PURPOSE: Interested in the general description of the tidal gates and how the coffer dam (temporary during construction) and diversion structure would impact the operation/water levels and get a description of the operation of the tide gates in general, as well as get information on the historic water surface elevations. Also, gain information on how coffer dams are typically constructed and how large they are.

CONVERSATION: Mariposa Landscapes operates the Washington Street tide gate as part of their maintenance contract. Luis asked me to e-mail him with specific questions and he will respond tomorrow.

Jennifer Buchanan

From: Luis Valenzuela <luisv@mariposa-ca.com>
Sent: Monday, October 12, 2015 9:39 AM
To: Jennifer Buchanan
Cc: Jorge Salazar
Subject: Re: Washington Street Tidal Gates and LA VAPP

Please contact me with any questions or comments regarding this email.

Thank You

Luis Valenzuela - Division Manager, Landscape Maintenance

MARIPOSA LANDSCAPES, INC.
"Blending nature and craftsmanship to create ultimate outdoor settings"
Cell 626-705-0622 Fax 626-960-8477
Email: luisv@mariposa-ca.com
Visit our web site!

On 10/12/2015 7:06 AM, Jennifer Buchanan wrote:

> Hi Luis,
>
> If you could please provide a little more information, we have a few more questions:
>
> - What does flushing entail? Using high and low tides to flush the canals at least twice per week depending on weather and available tides.
> - How much water, for how long, etc.? We do not have a quantity of water, but it takes approximately 2 to 3 hours to fill depending on the tides.
> - Are they just opening gates or are they adding water? We add water using the tides.
> - Is it scheduled? We do generate a monthly schedule, but always subject to change depending on the weather.
> - Do they flush if it's raining? Yes.
> - Are the gates normally left open?
>
> I understand you would also like to know if the construction of the coffer dam will hinder the flushing of the canal twice a week. Please let me know if you have any other questions and I will get the answers to you as soon as I can.
>
> Thank you,
>
> Jennifer
>
> Jennifer Buchanan, GISP
> Senior Hydrologist
> Watearth, Inc.
> jbuchanan@watearth.com
> 916.240.7010
> 1.800.519.3774 (F)

Visit our website at: www.watearth.com

From: Luis Valenzuela [mailto:luisv@mariposa-ca.com]
Sent: Tuesday, September 29, 2015 12:44 PM
To: Jennifer Buchanan
Subject: Re: Washington Street Tidal Gates and LA VAPP

Answers in Red.

Please contact me with any questions or comments regarding this email.

Thank You

Luis Valenzuela - Division Manager, Landscape Maintenance

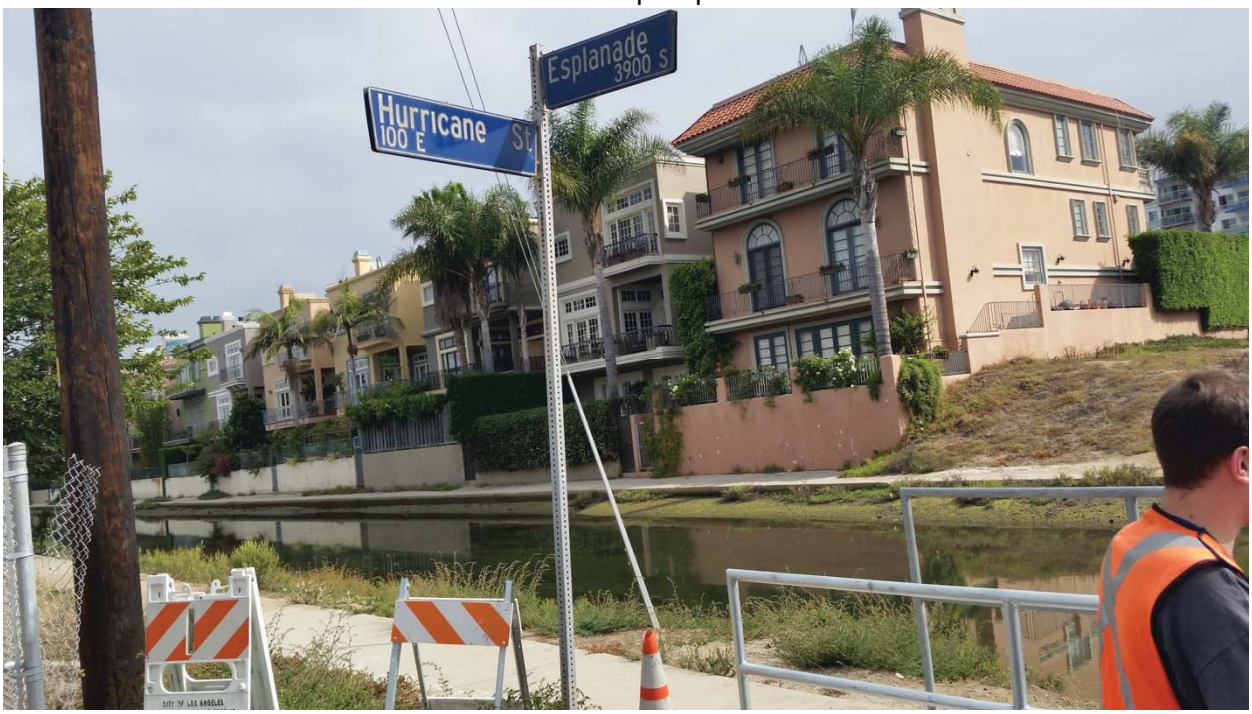
MARIPOSA LANDSCAPES, INC.
"Blending nature and craftsmanship to create ultimate outdoor settings"
Cell 626-705-0622 Fax 626-960-8477
Email: luisv@mariposa-ca.com
Visit our web site!

On 9/17/2015 2:55 PM, Jennifer Buchanan wrote:

> Hi Luis,
>
> Thank you for your time in answering a few questions relating to maintenance of the Washington Street tidal gates. Any information you can provide will be helpful in the planning of the proposed LA Venice Auxiliary Pumping Plant. My questions are as follows:
>
> 1. Please describe the operation of the Washington Street tide gate. We flush twice per week. Day of the week varies due to changes of tides.
> 2. Would temporary construction of a coffer dam and diversion structure in the Grand Canal adjacent to the existing Venice Pumping Plant impact the operation or water levels? I am not sure because I am not familiar with the project.
> 3. Do you have information on the historic water surface elevations in Grand Canal? I do not.
>
> Sincerely,
>
> Jennifer
>
> Jennifer Buchanan, GISP
> Senior Hydrologist
> Watearth, Inc.
> jbuchanan@watearth.com
> 916.240.7010
> 1.800.519.3774 (F)
>
> Visit our website at: www.watearth.com

APPENDIX O
SITE PHOTOS/DESCRIPTIONS

Venice pump station



Looking at Grand Canal at Hurricane and Esplanade at pump station

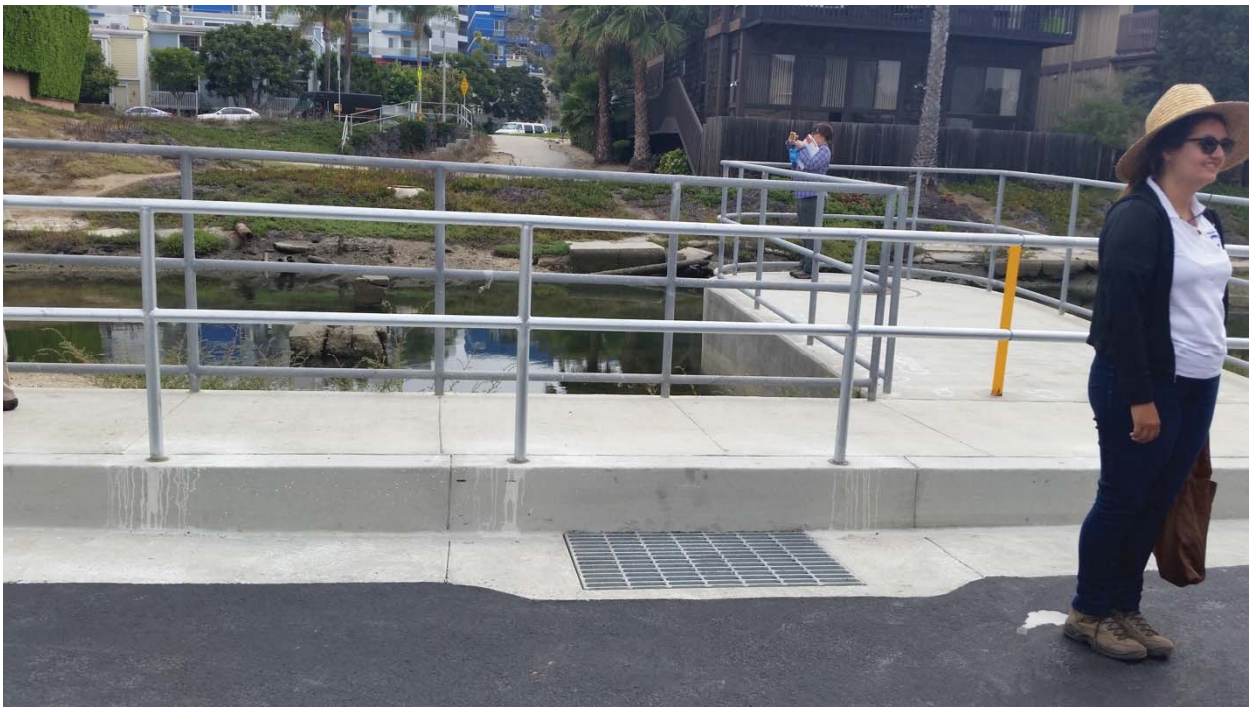
Looking downstream on Grand Canal towards Ballona Lagoon from pump station

Looking upstream on grand canal from pump station

Storm outfall from Hurricane St. into Grand Canal at road between existing and auxiliary sites

Close up of storm outfall from Hurricane St. into Grand Canal

Looking across Grand Canal at optional lot from existing pump station



Inlet on Hurricane St. into Grand Canal

Looking downstream on Grand Canal towards Ballona Lagoon from pump station

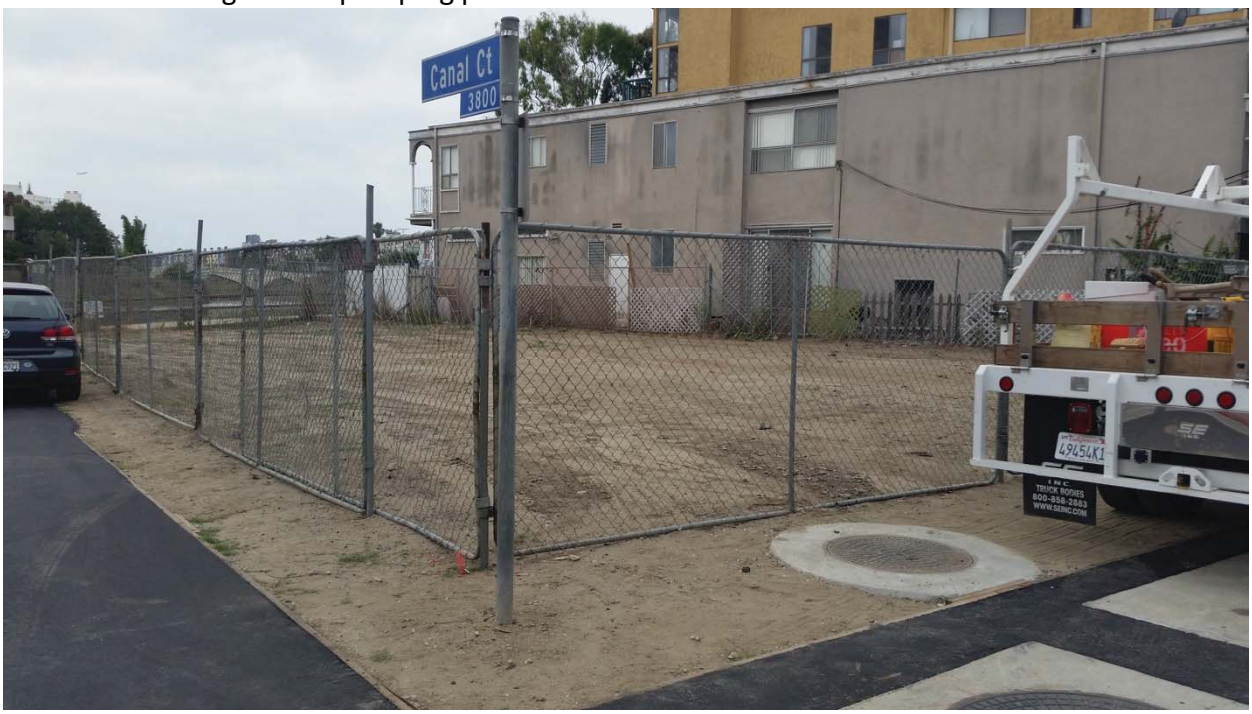
Unidentified outfall under existing pump station into Ballona Lagoon

Unidentified outfall under existing pump station (2)

Looking at site of auxiliary pumping plant from existing plant side of street

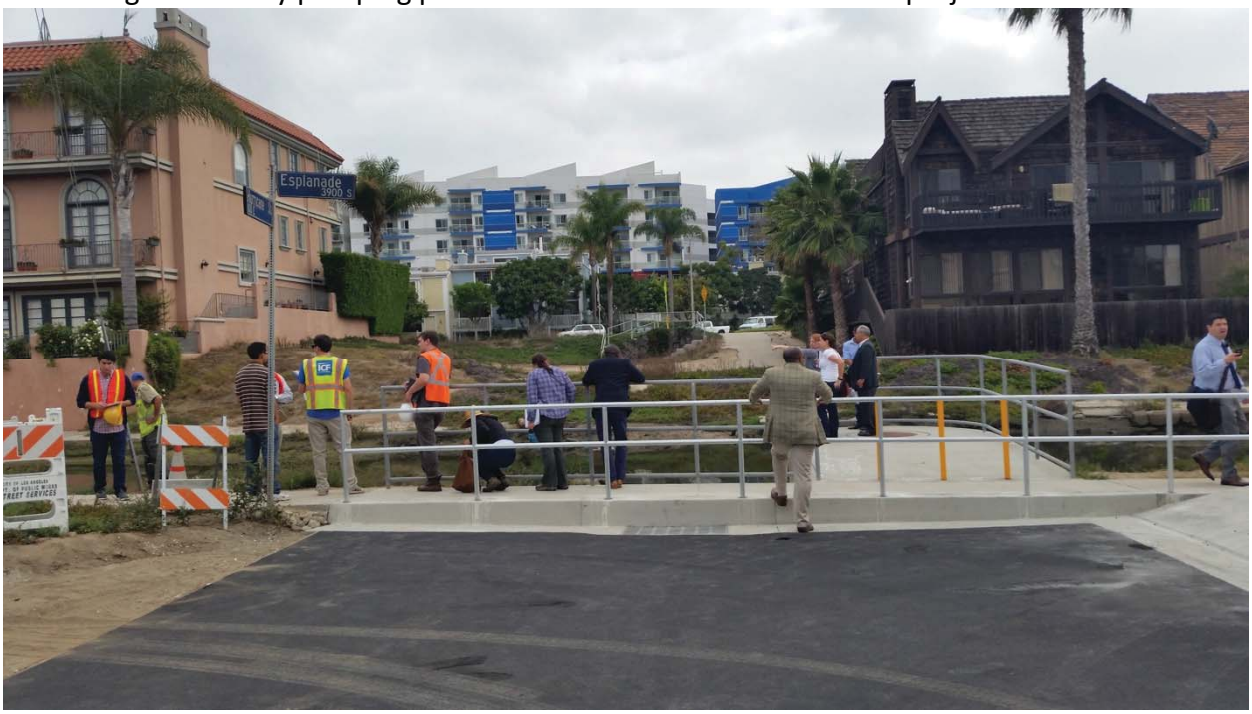
Looking down Hurricane St. towards grand canal with existing plant on right and auxiliary plant on left.

Existing Venice pumping plant from end of Hurricane St. at the Grand Canal



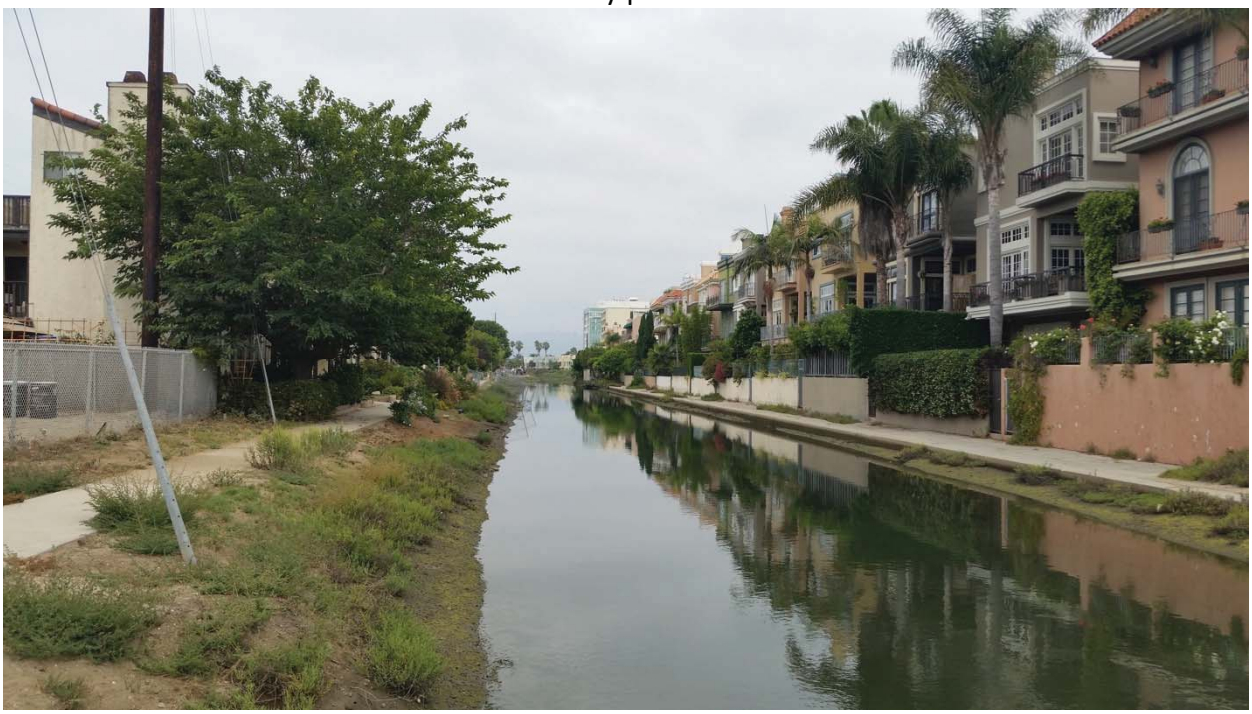
Primary staging area adjacent to Ballona Lagoon from Hurricane St.

Looking at auxiliary pumping plant site and manholes for manifold project on Hurricane St.



Looking across Grand Canal at optional staging site-2 lots-from Hurricane and Esplanade

Auxiliary plant site



Looking upstream along Grand Canal with Auxiliary plant site on left

Close up of optional staging lot across Grand Canal

Close up 2 of optional staging lot across Grand Canal

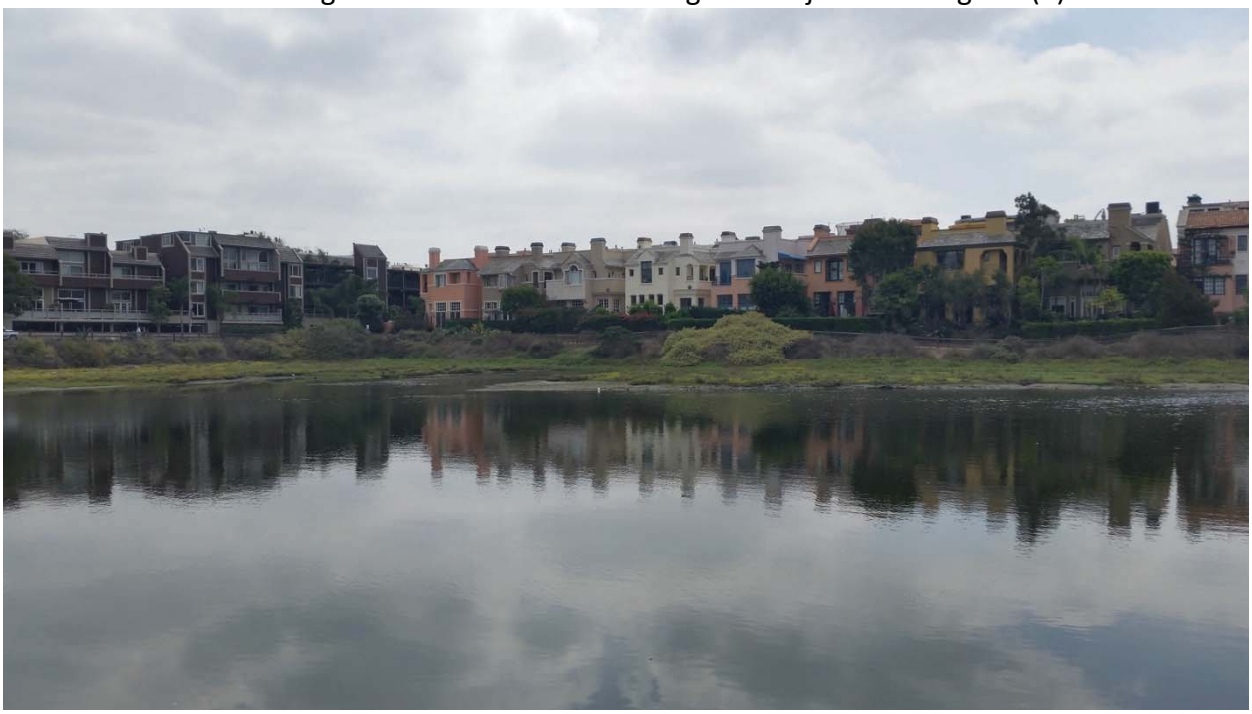
Close up 3 of optional staging lot across Grand Canal

Side slope of Grand Canal looking upstream with auxiliary plant site on left

Side slope of Grand Canal looking upstream with auxiliary plant site on left (2)

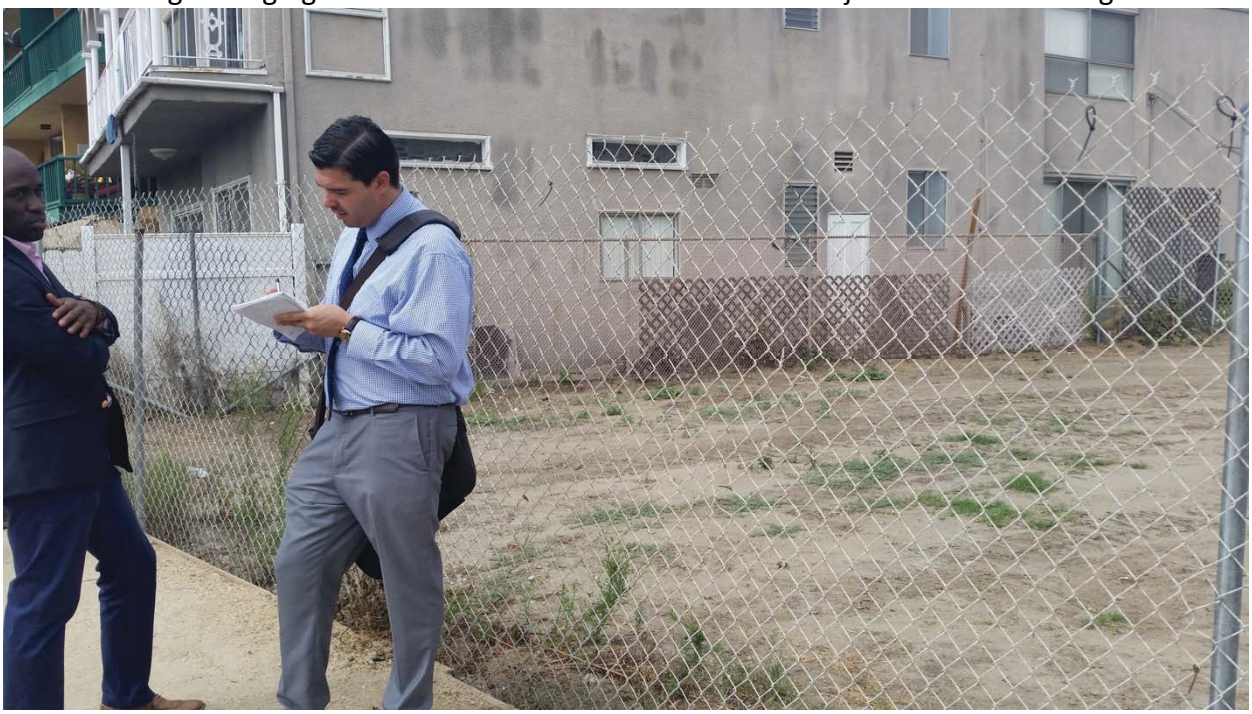
Ballona Lagoon trail on back side of staging lot adjacent to Lagoon

Ballona Lagoon trail on backside of stagin lot adjacent to Lagoon (2)



View of Ballona Lagoon from South Side of existing plant

Looking at staging lot towards Hurricane from back side adjacent to Ballona Lagoon.



Staging lot from back

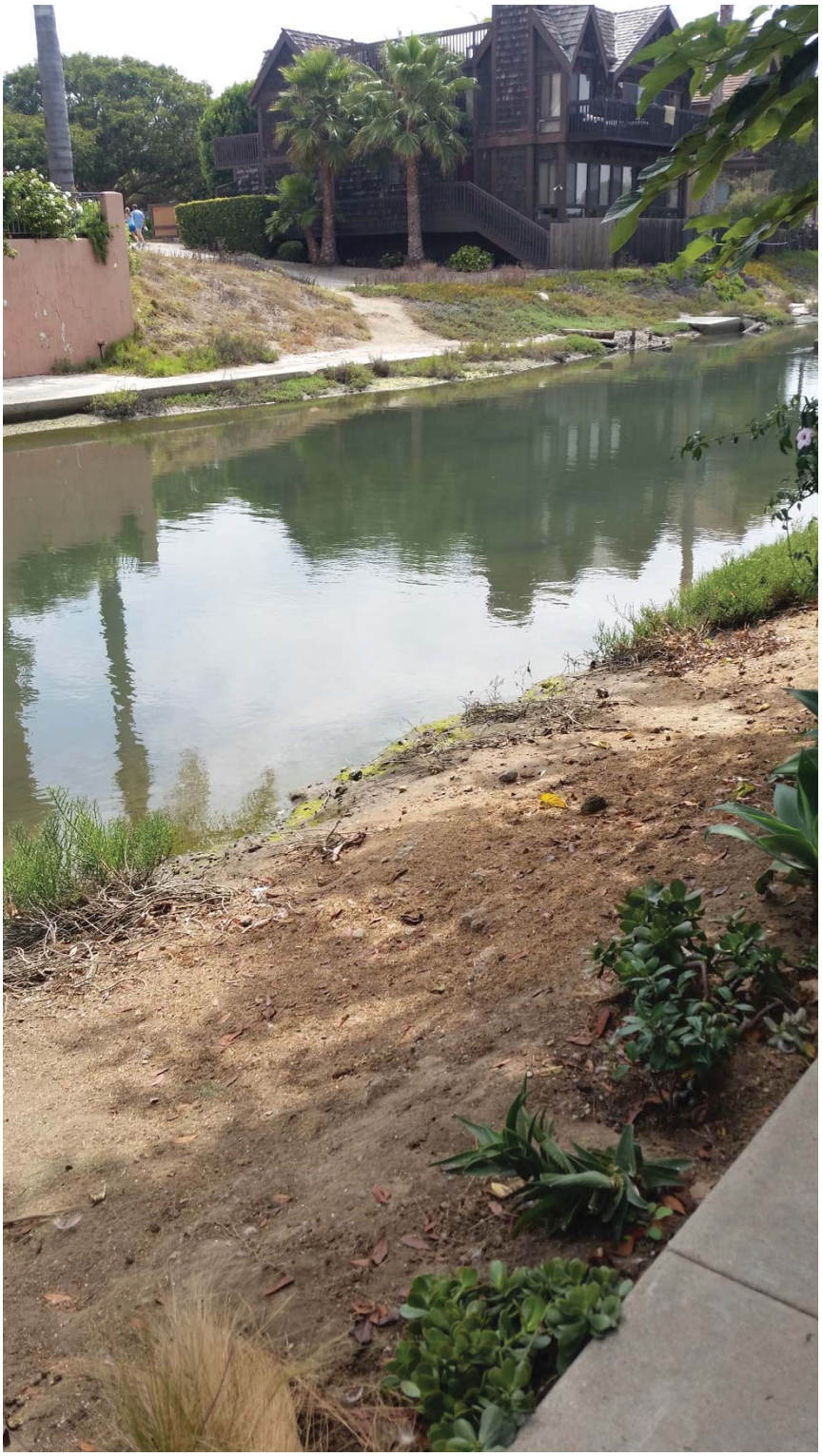
Staging lot from back (2)

Looking downstream towards existing plant with auxiliary site on right and existing natural ground

Looking across Grand Canal at optional staging lot from upstream of existing and auxiliary plant sites

Auxiliary plant site from Grand Canal-Esplanade side

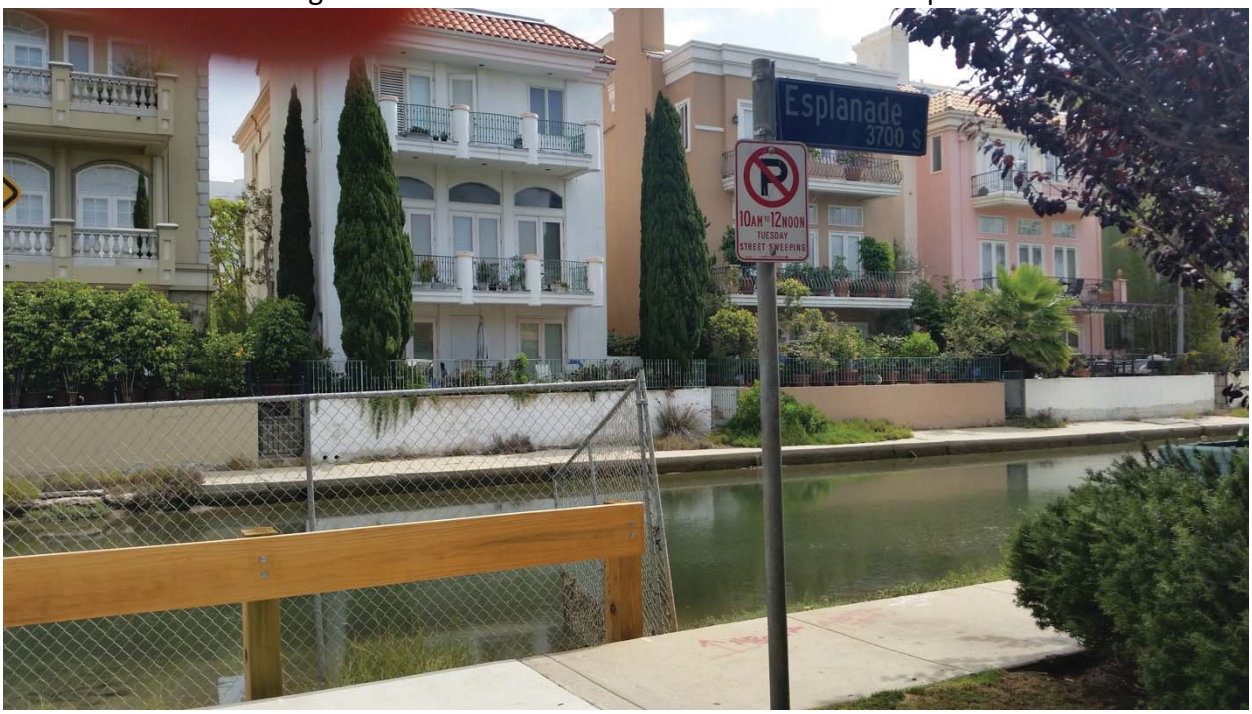
Natural ground along Grand Canal with erosion potential near auxiliary site



Bare soil on bank of Grand Canal near auxiliary site and looking across stream at optional staging site

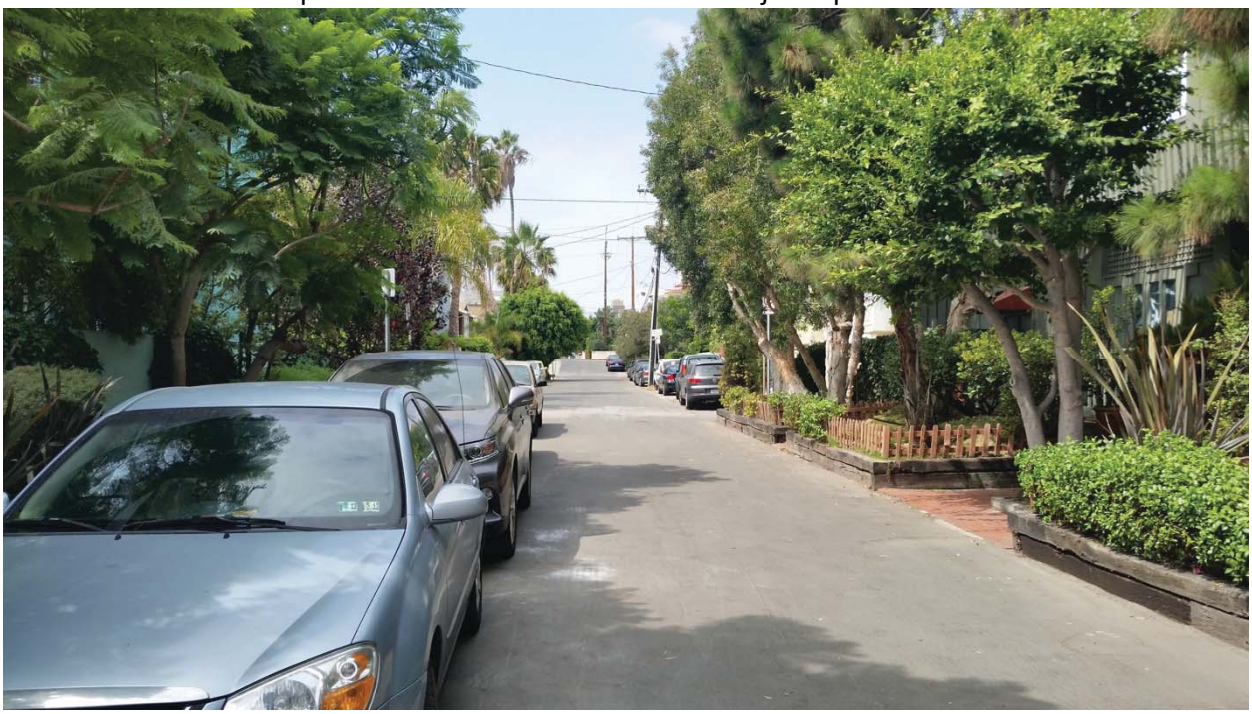
Looking upstream at Grand Canal at Galleon and Esplanade

Looking downstream at Grand Canal at Galleon and Esplanade

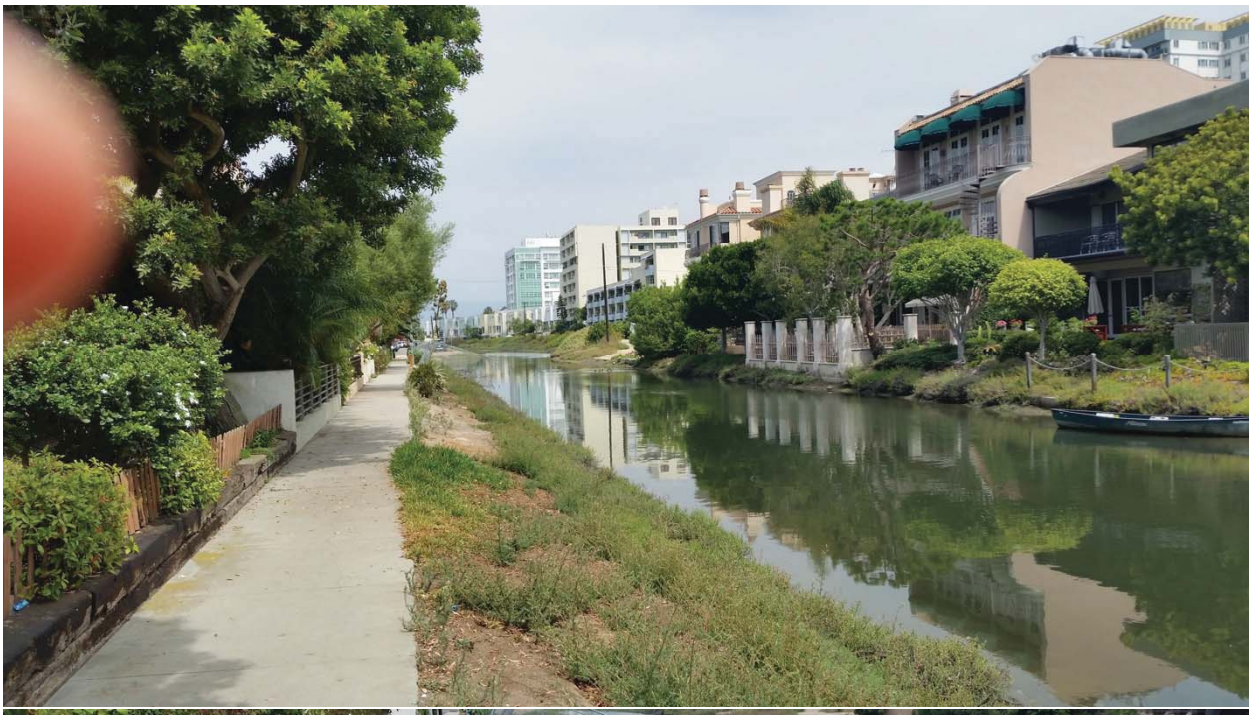


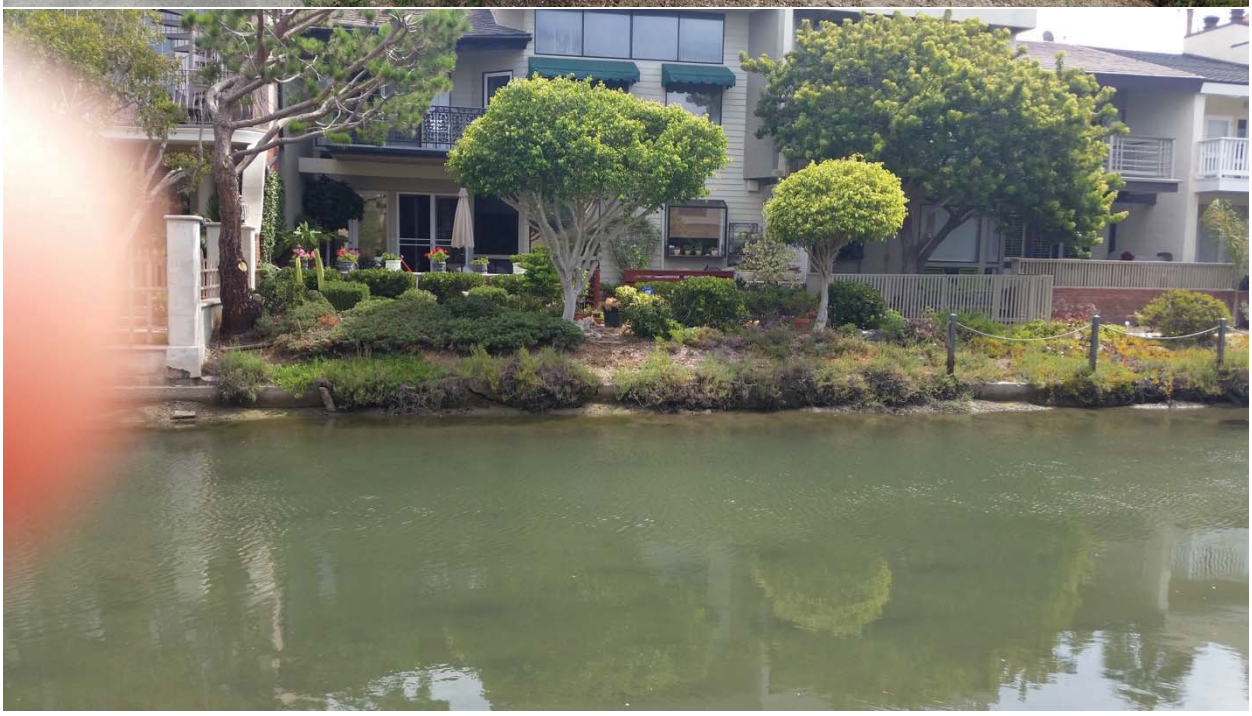
Esplanade and unnamed intersection just upstream of Galleon

Inlet at Esplanade and unnamed intersection just upstream of Galleon



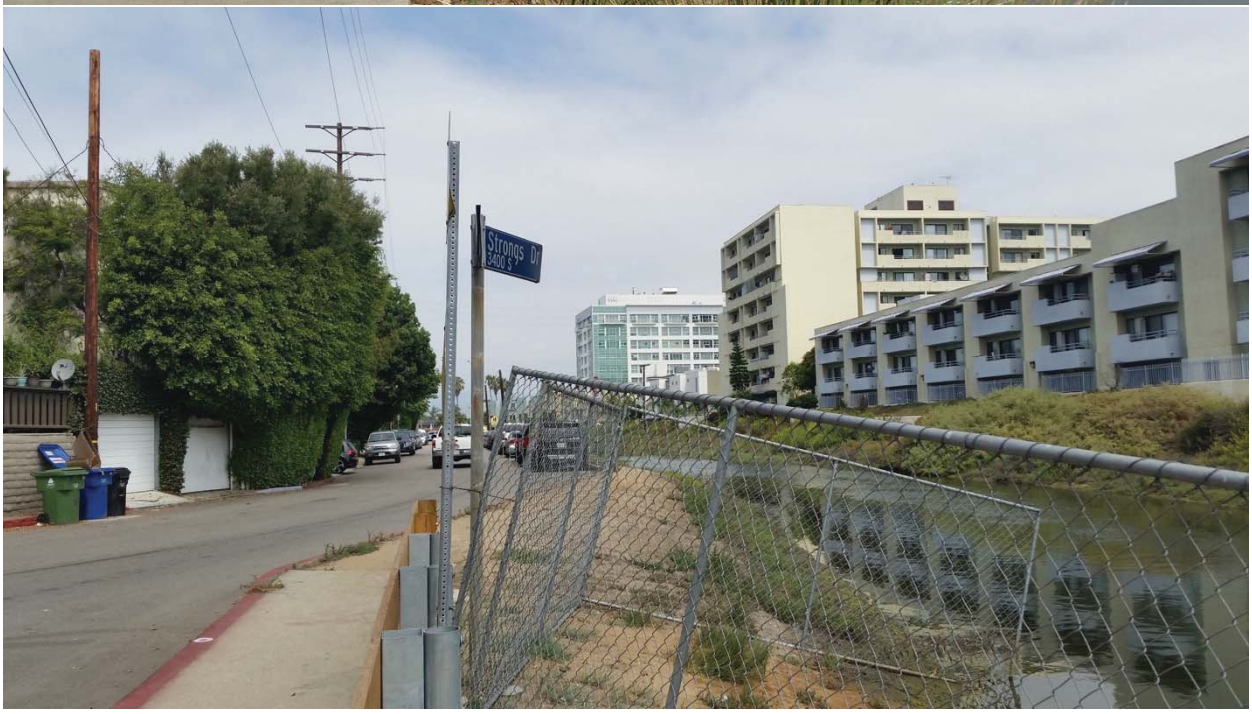
Looking away from Grand Canal at unnamed street just upstream of Galleon



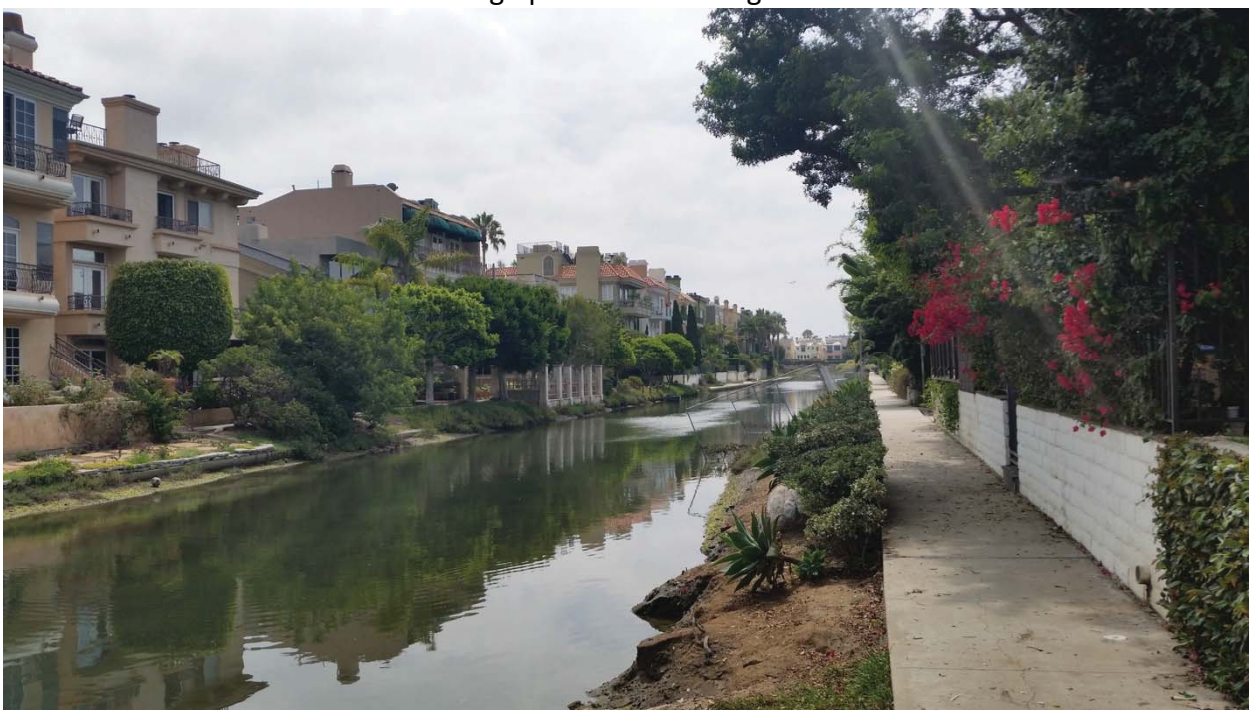


Esplanade and second unnamed intersection upstream of Galleon

Looking downstream from Esplanade and second unnamed intersection upstream of Galleon


Strongs Dr
3400 S

Looking upstream at Strongs Drive



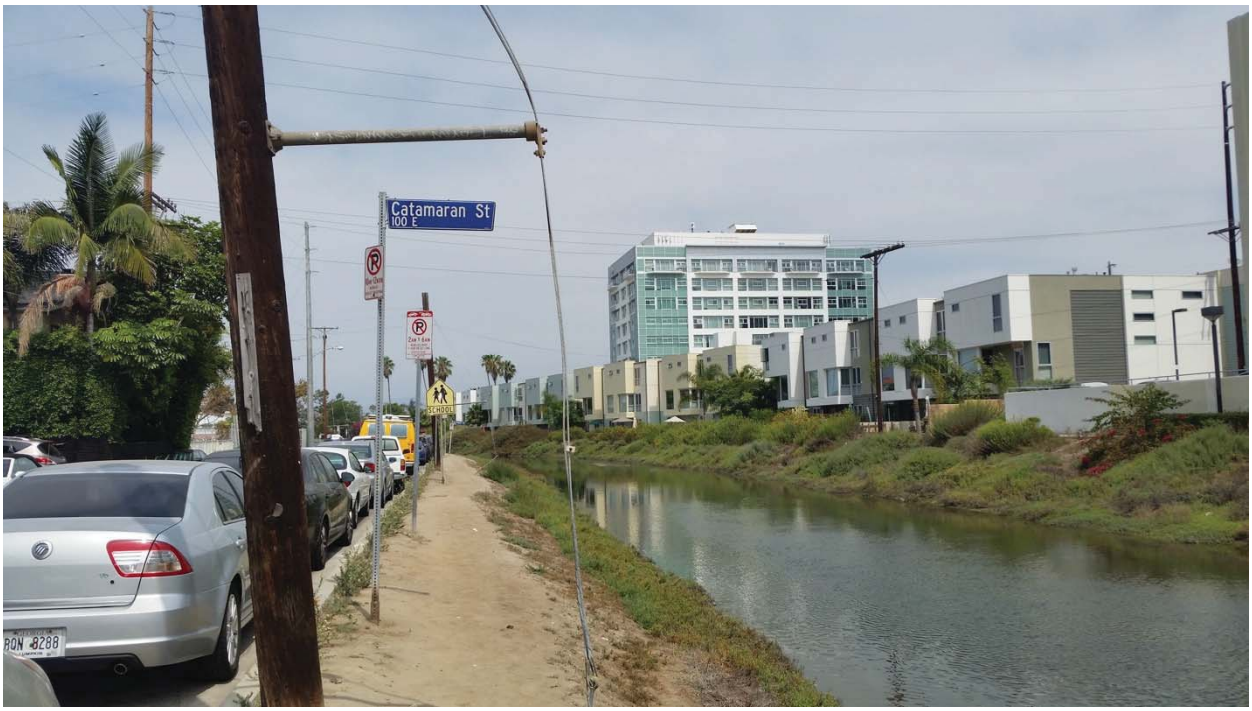
Looking downstream at Strongs Drive

Looking at Strongs Drive heading away from Grand Canal

Inlet at Strongs Drive and Esplanade into Grand Canal

Looking upstream at Strongs Drive

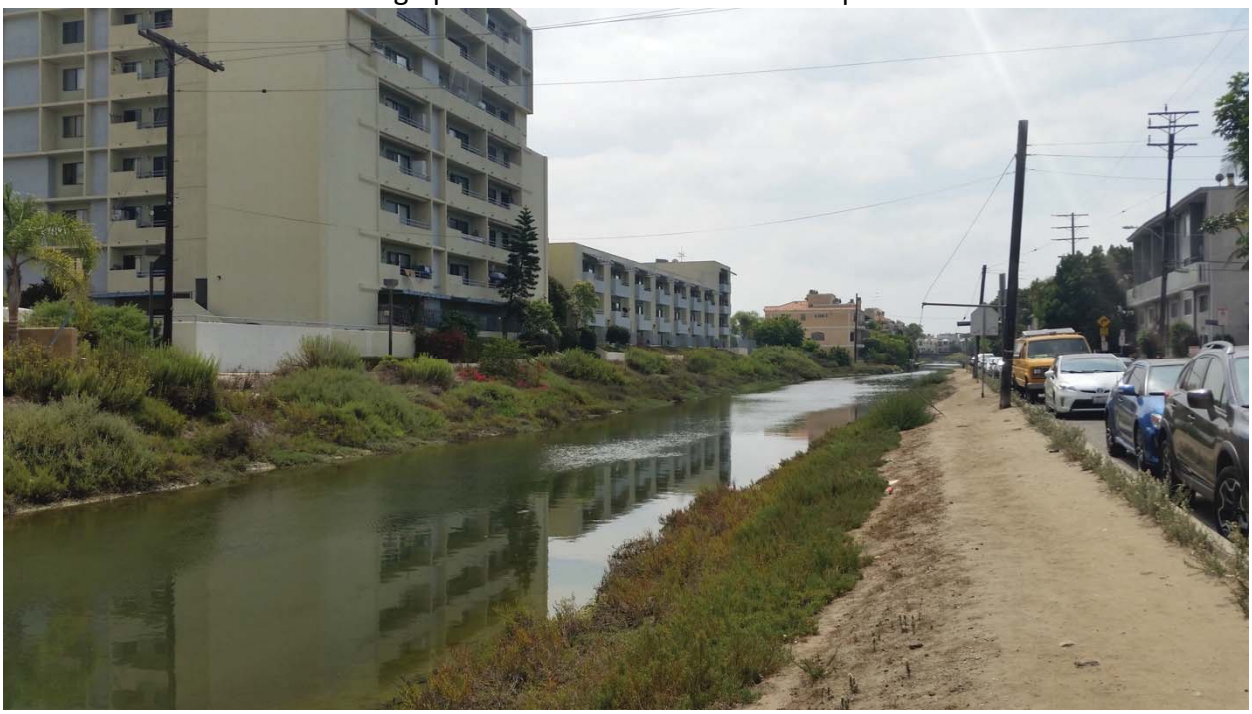
Natural ground near Strongs Drive



Looking upstream at Catamaran St. and Esplanade

Looking downstream at Catamaran St. and Esplanade

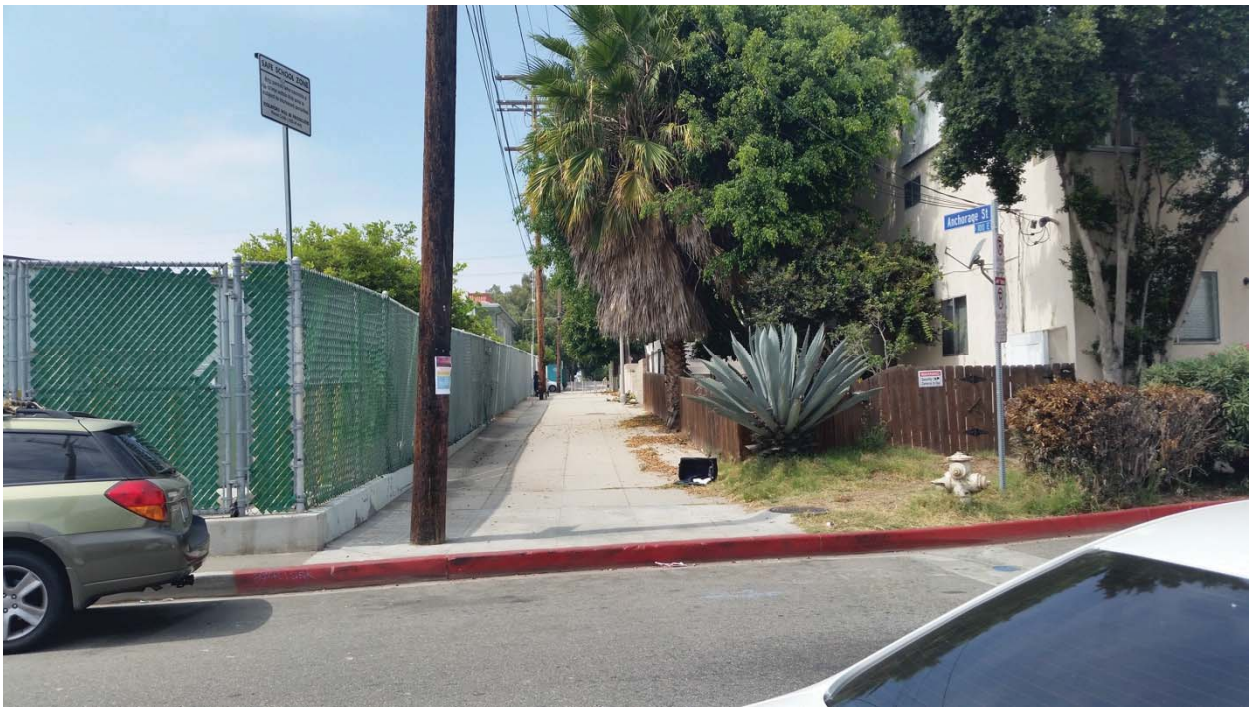
Looking upstream at Buccaneer St and Esplanade



Looking downstream at Buccaneer St. and Esplanade

Looking upstream at Anchorage and Esplanade

Looking downstream at Anchorage and Esplanade



Looking towards Anchorage Alley from Grand Canal

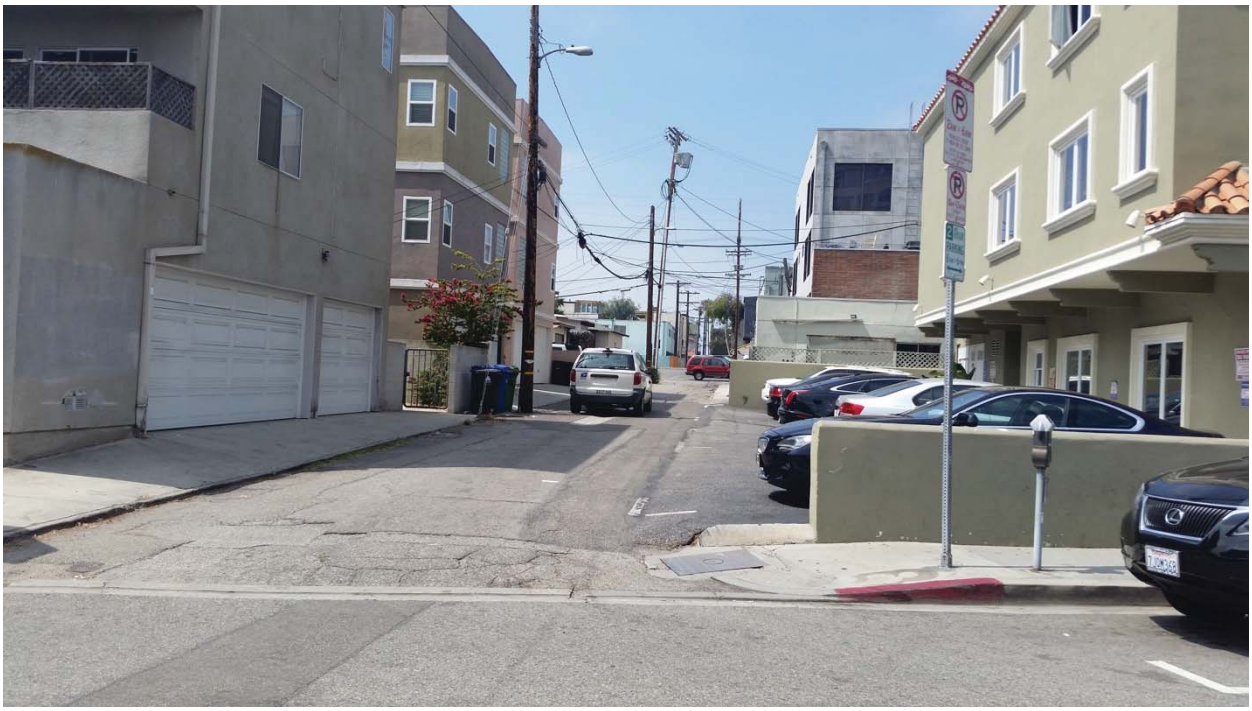
Looking upstream towards Washington

Looking upstream towards Washington (2)

Looking upstream at Washington intersection

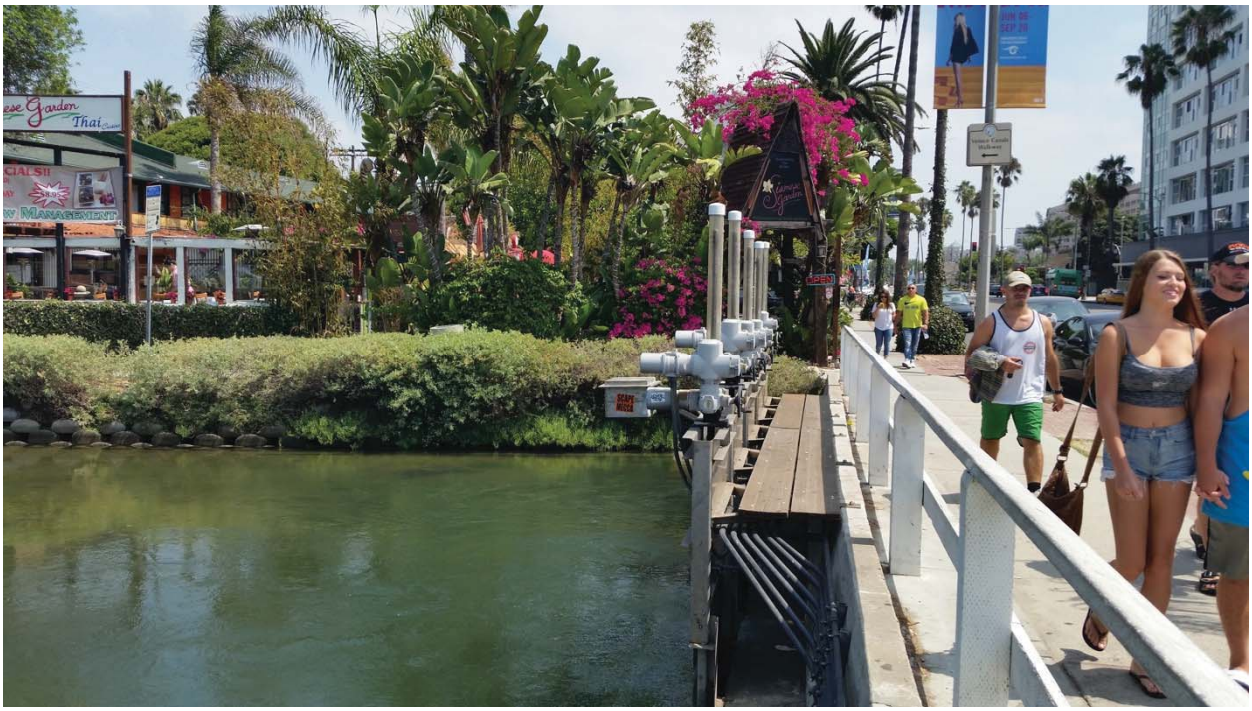
Looking downstream from south side of Washington

Looking upstream at face of crossing structure at Washington



Looking down alley just south of Washington away from Grand Canal

Side view of Grand Canal and tide gates at upstream side of Washington from Strongs



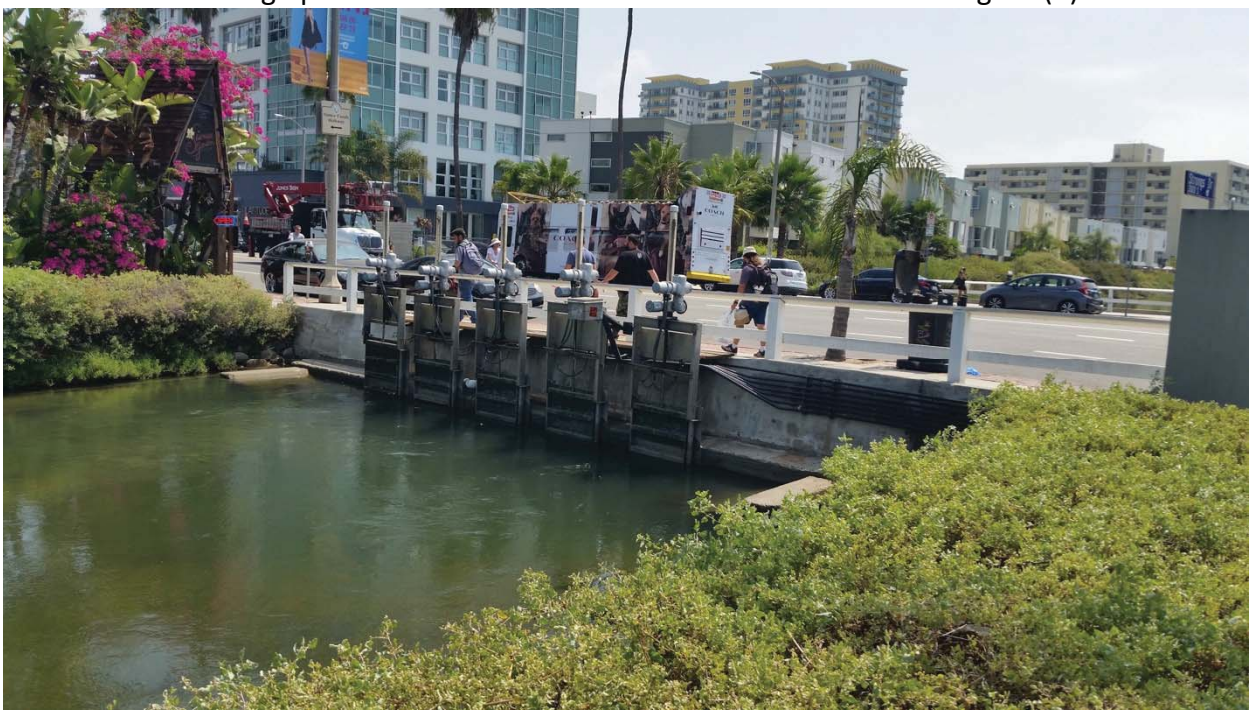
Looking towards tide gates at upstream side of Washington from Strongs Drive.

Looking towards tide gates at upstream side of Washington from Strongs Drive

Looking upstream on Grand Canal-Venice Canals from Washington

Looking upstream on Grand Canal-Venice canals from Washington (2)

Looking upstream on Grand Canal-Venice canals from Washington (3)



Looking downstream at tide gates on upstream side of Washington

Looking upstream towards first foot bridge north of Washington

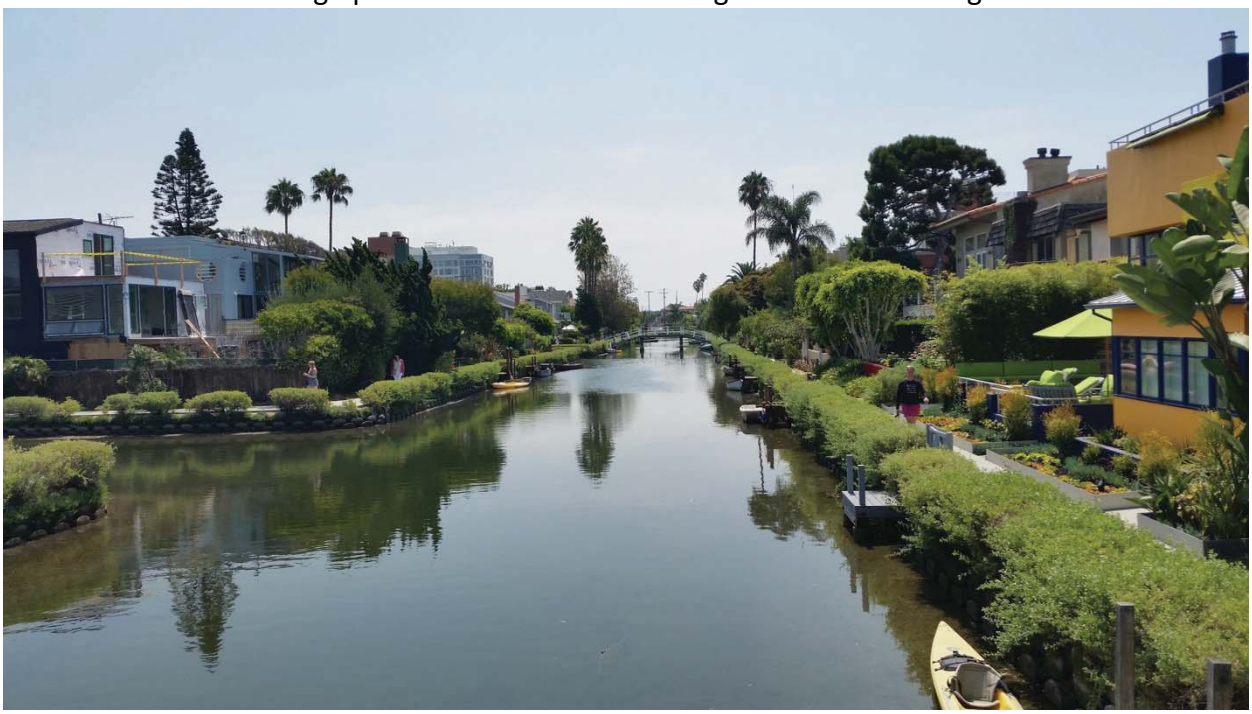
Looking downstream from first foot bridge North of Washington

Looking upstream from first foot bridge North of Washington

Looking up first side canal just upstream of first foot bridge north of Washington

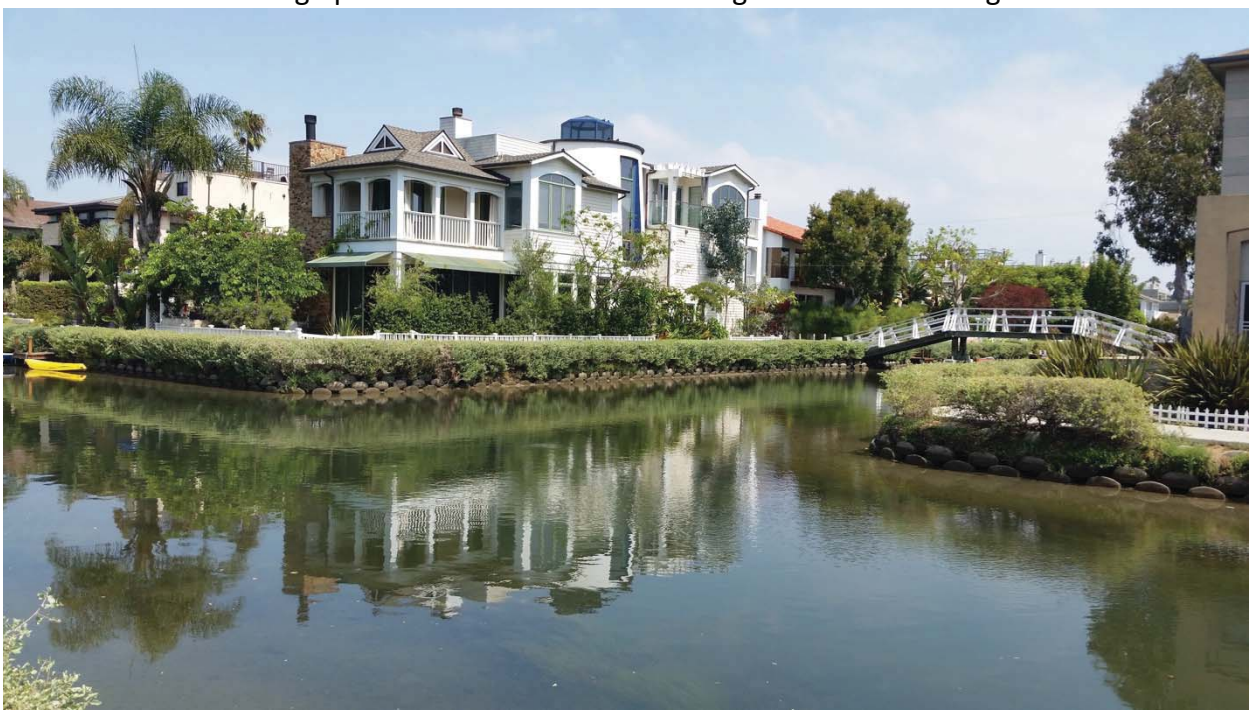
Looking up second side canal just downstream of second foot bridge North of Washington

Looking upstream at second foot bridge North of Washington



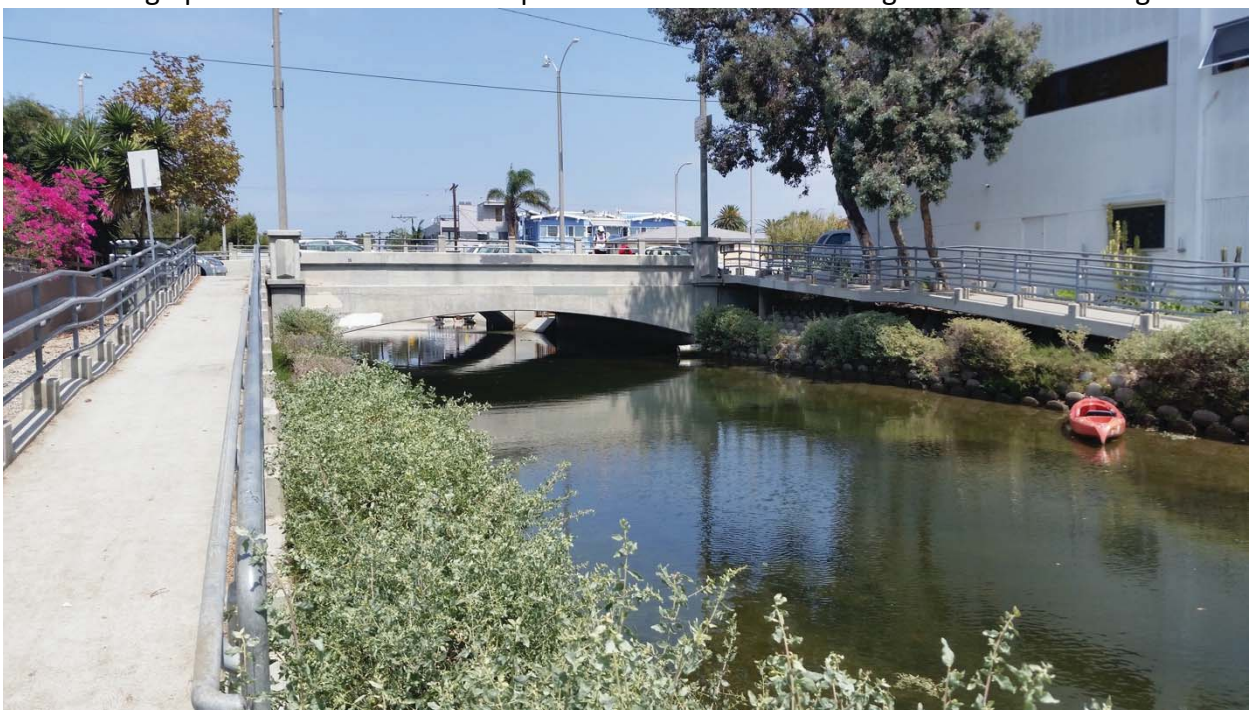
Looking downstream from second foot bridge North of Washington

Looking upstream from second foot bridge North of Washington



Looking up third side canal from second foot bridge North of Washington

Looking up fourth side canal from upstream of second foot bridge North of Washington



Looking upstream towards South Venice Blvd.

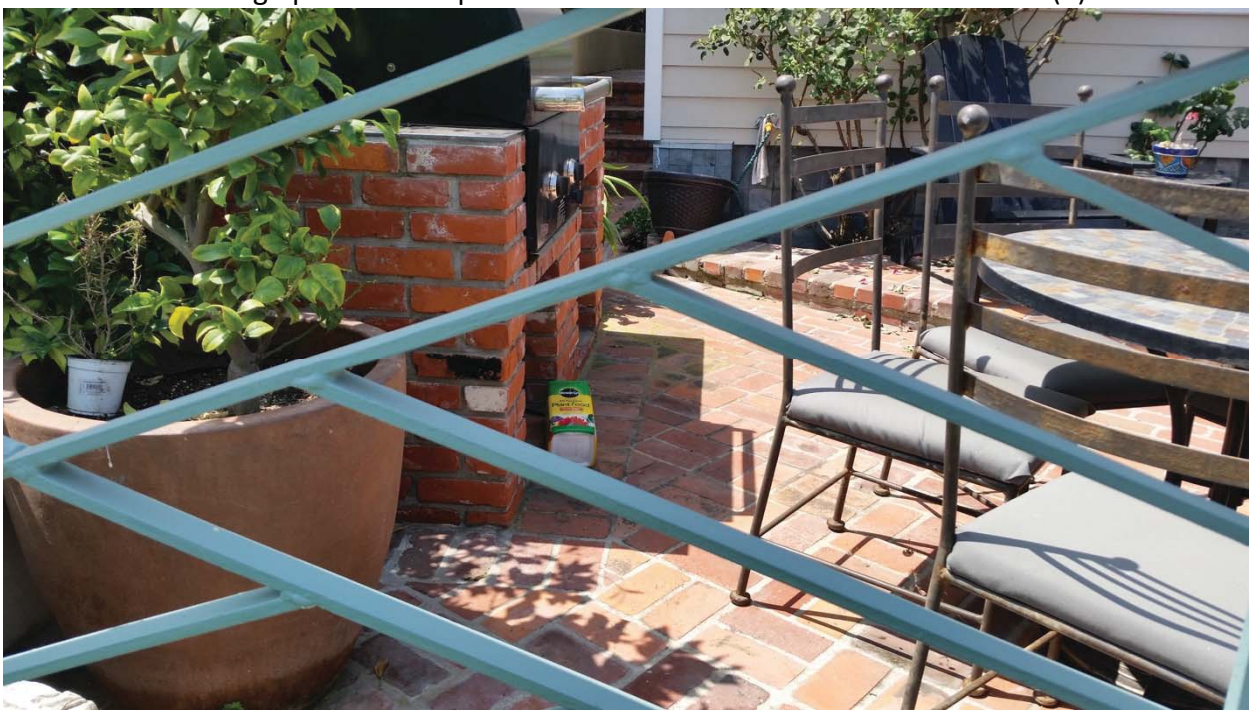
Looking downstream from South Venice Blvd.

Looking between North and South Venice Blvd.

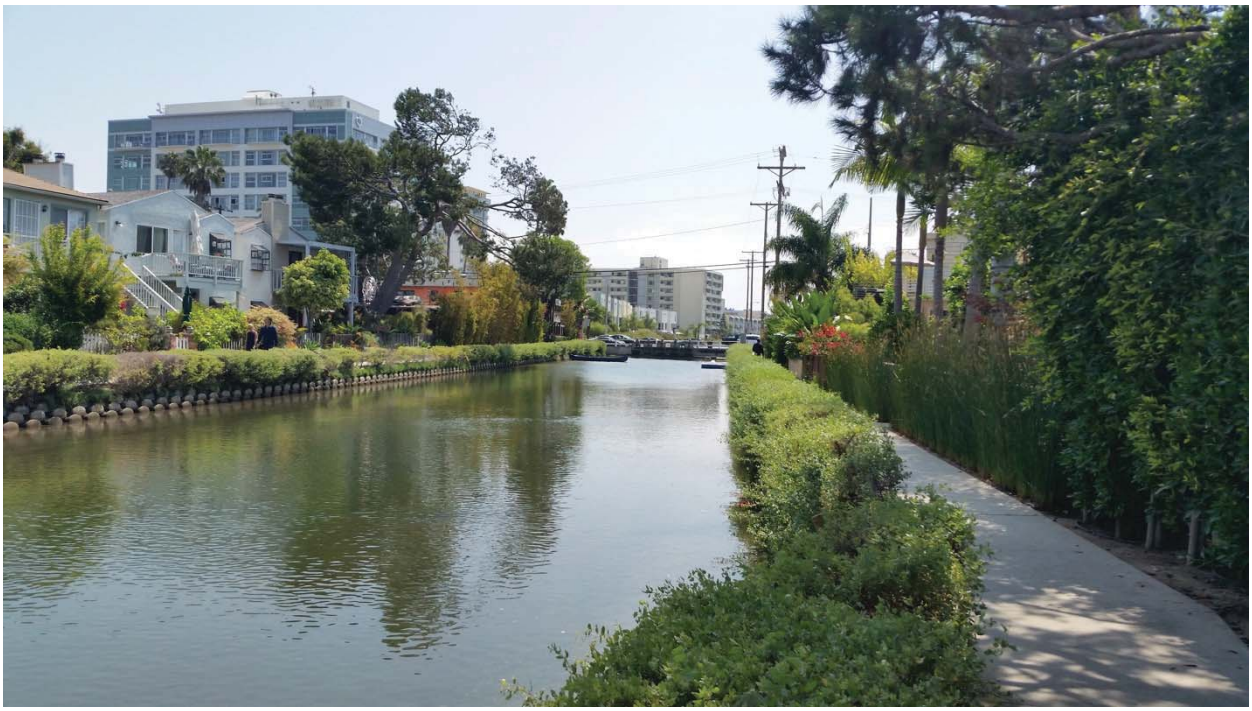
Looking upstream at end of canal from North Venice Blvd

Looking downstream at upstream face of North Venice Blvd. bridge

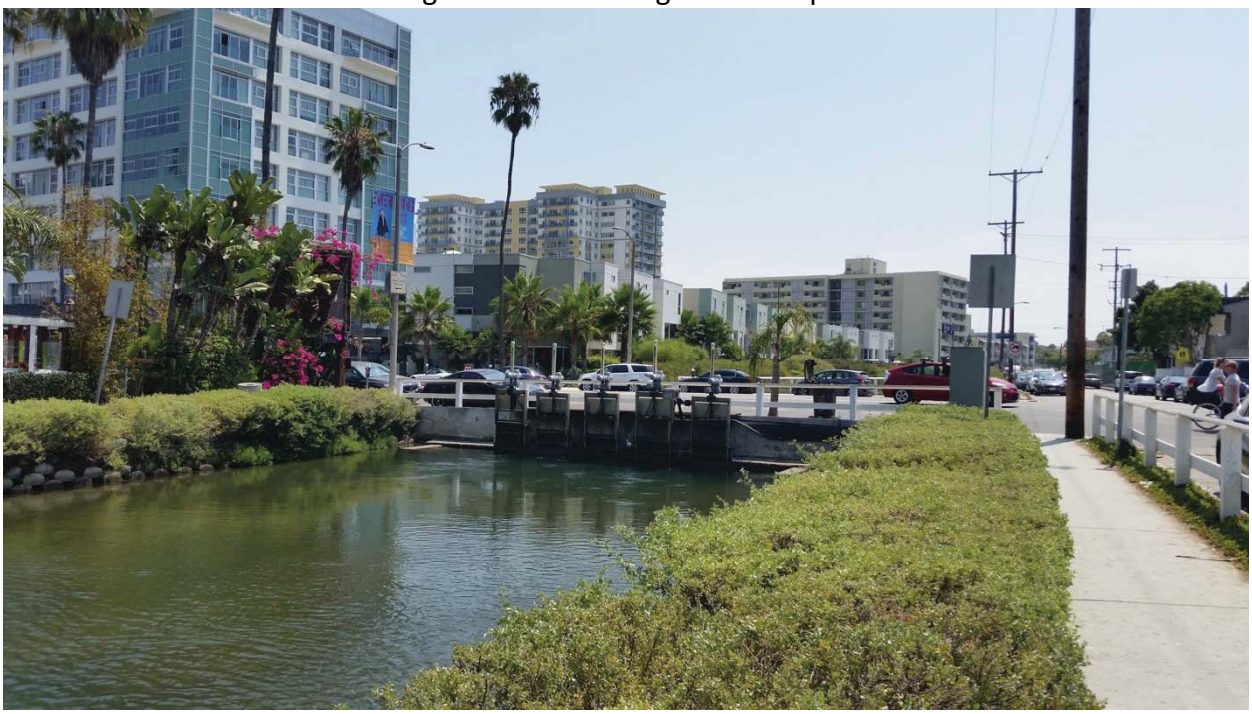
Looking upstream at upstream end of canal from North Venice Blvd (2)



Miracle Fertilizer example adjacent to Canal (water quality issue)

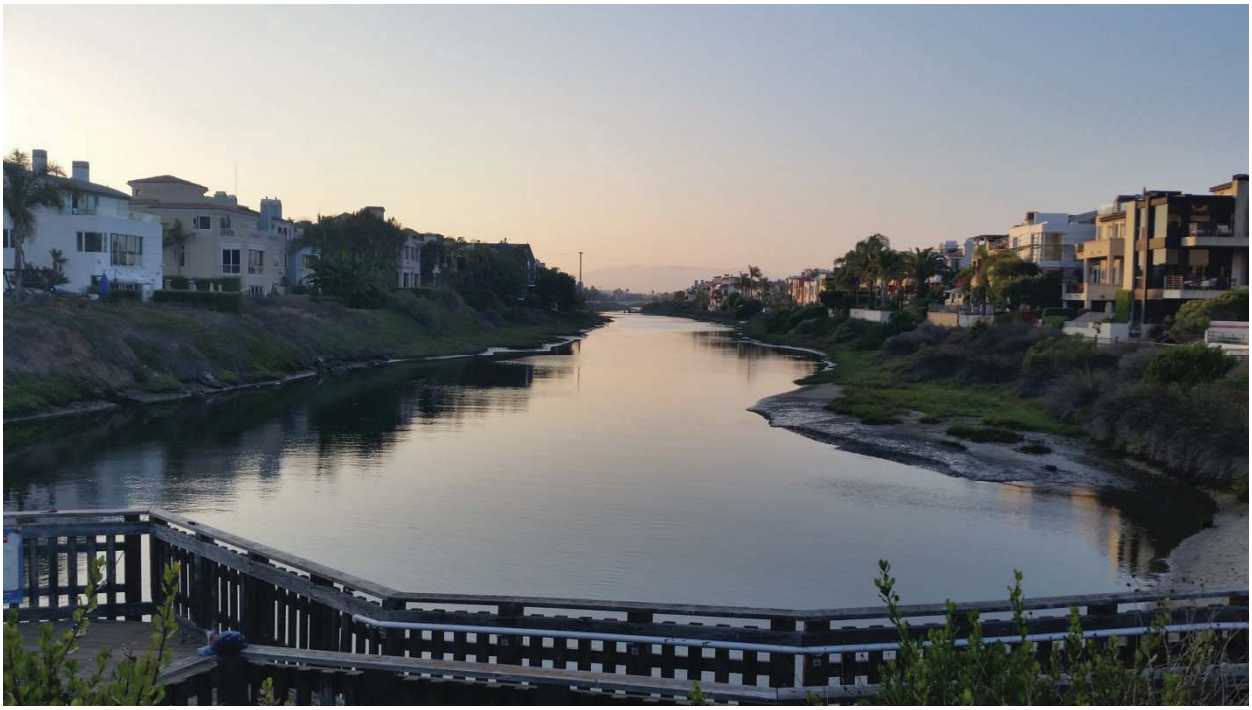


Looking towards Washington from upstream

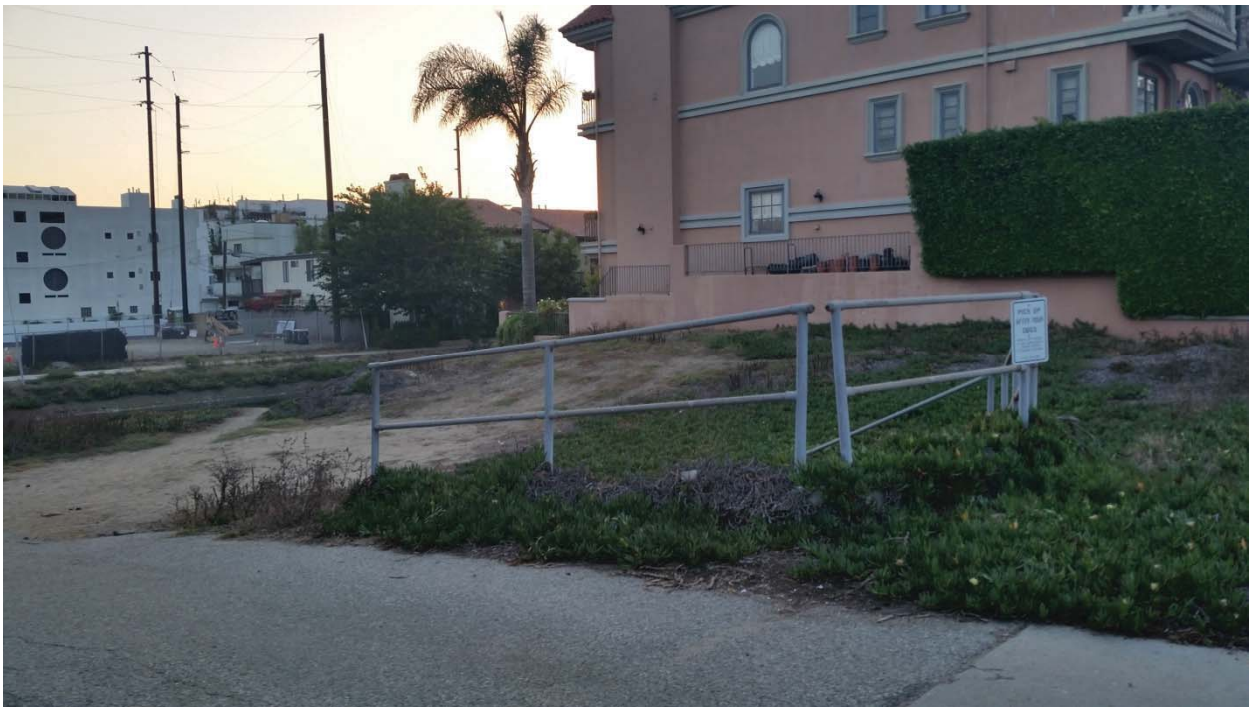


Looking towards Washington tide gates from upstream

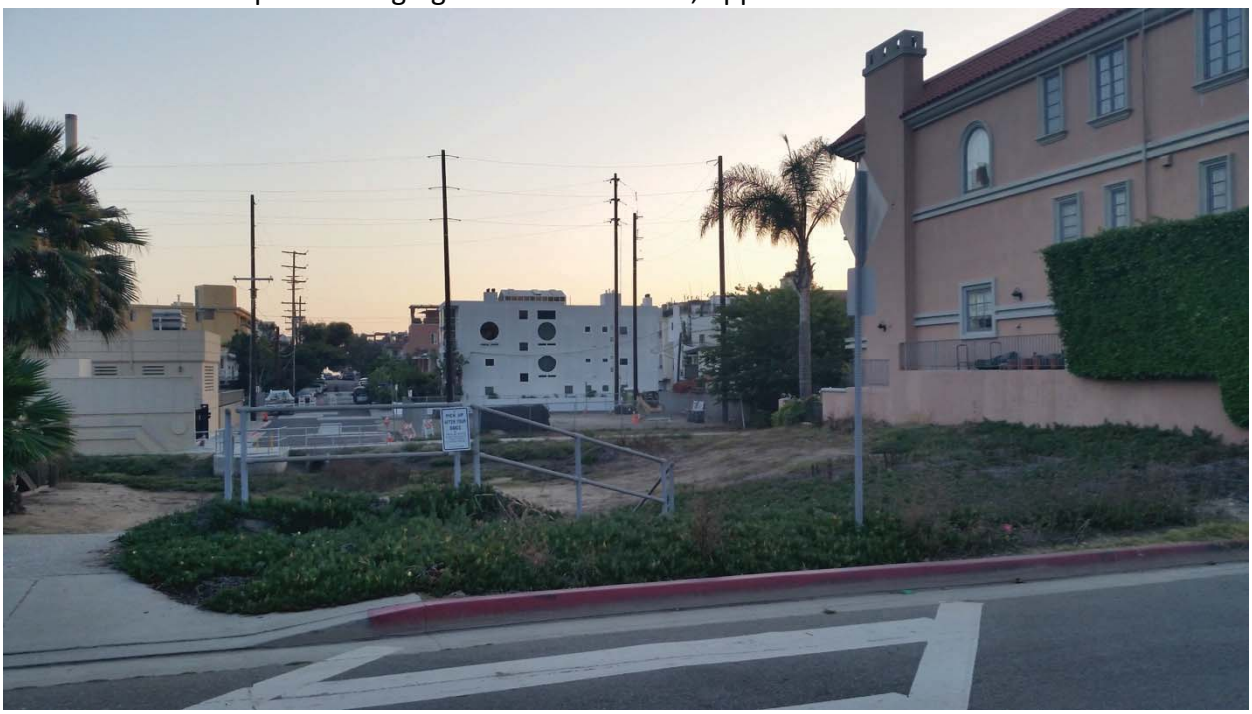
Ballona Creek



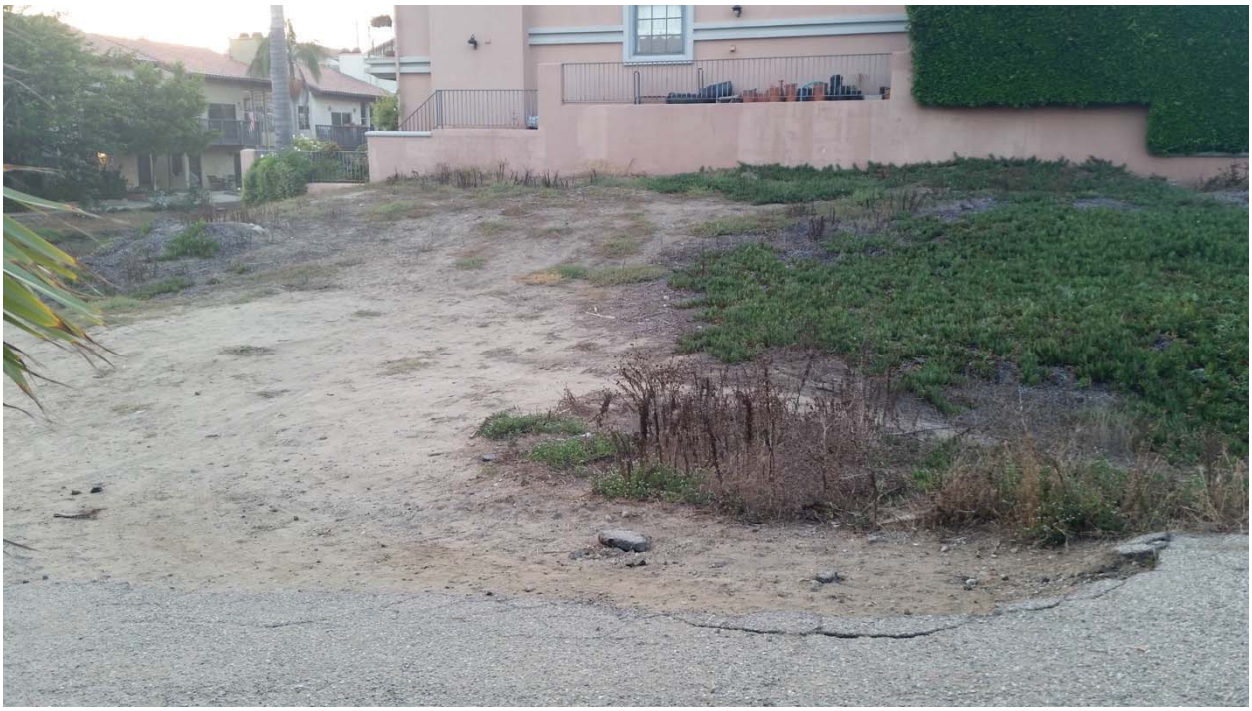
Downstream of Ballona Lagoon



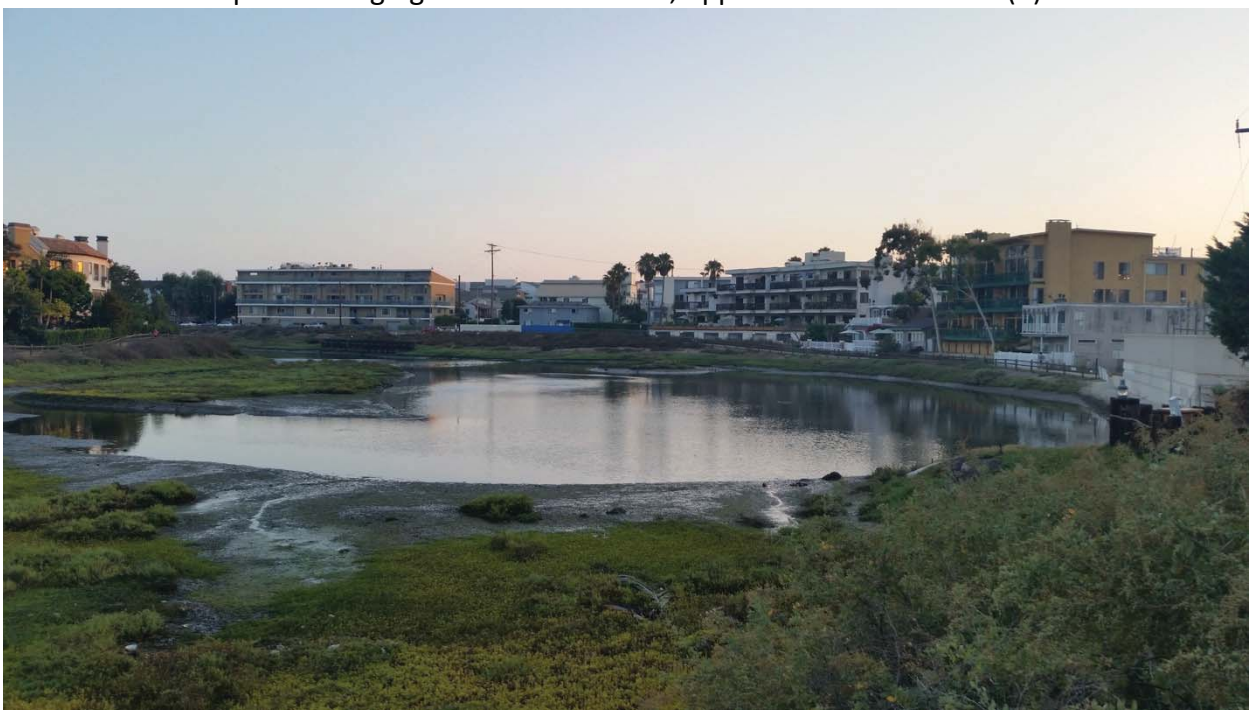
Optional staging lot from front side, opposite of Grand Canal



Optional staging lot from front side, opposite of Grand Canal (2)

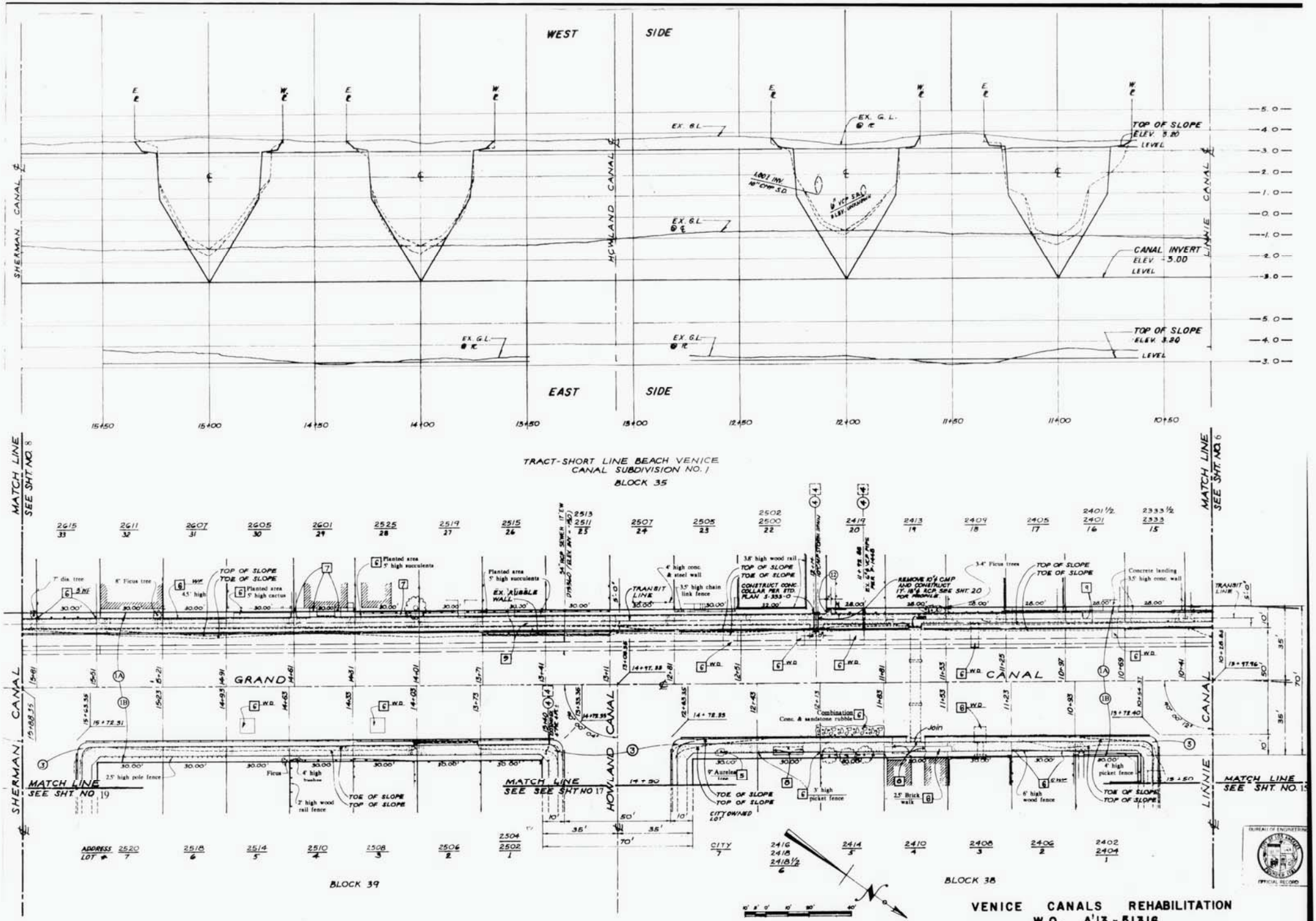


Optional staging lot from front side, opposite of Grand Canal (3)



Looking towards Ballona Lagoon from opposite side of canal with existing plant in extreme right.

APPENDIX P
CROSS SECTION OF GRAND CANAL, PLAN SHEET D-29976, VENICE CANALS REHABILITATION, SHEET NO. 7 OF 26



VENICE CANALS REHABILITATION
W.O. A'13-51316

HAER No. CA-124-44